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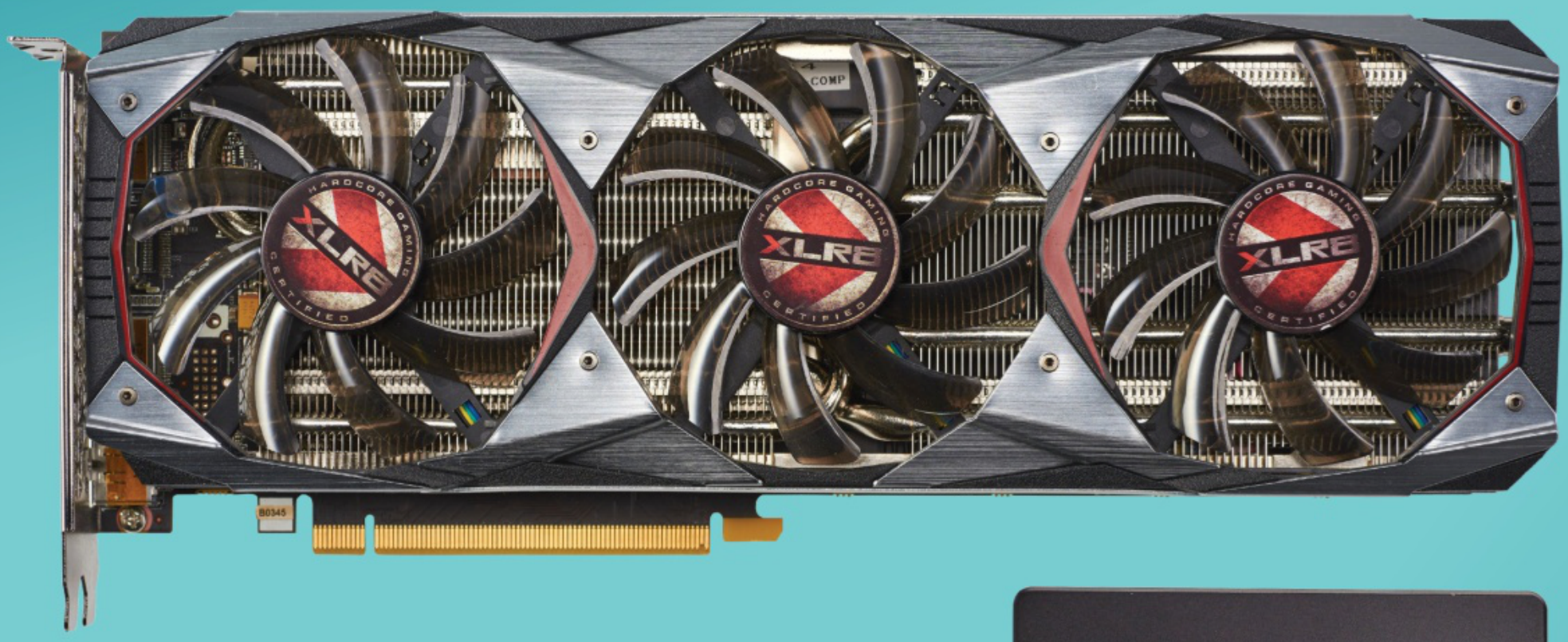

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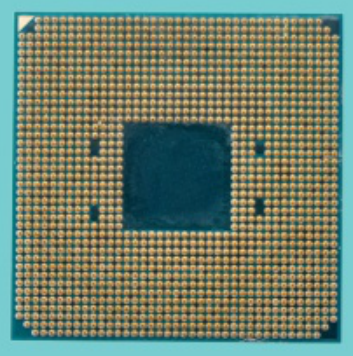

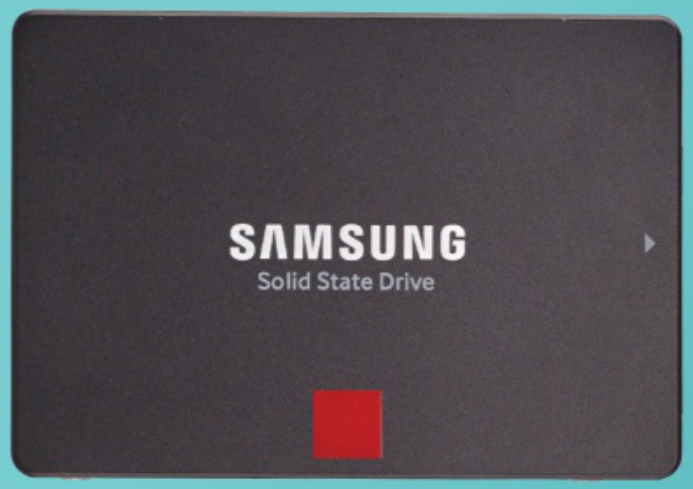

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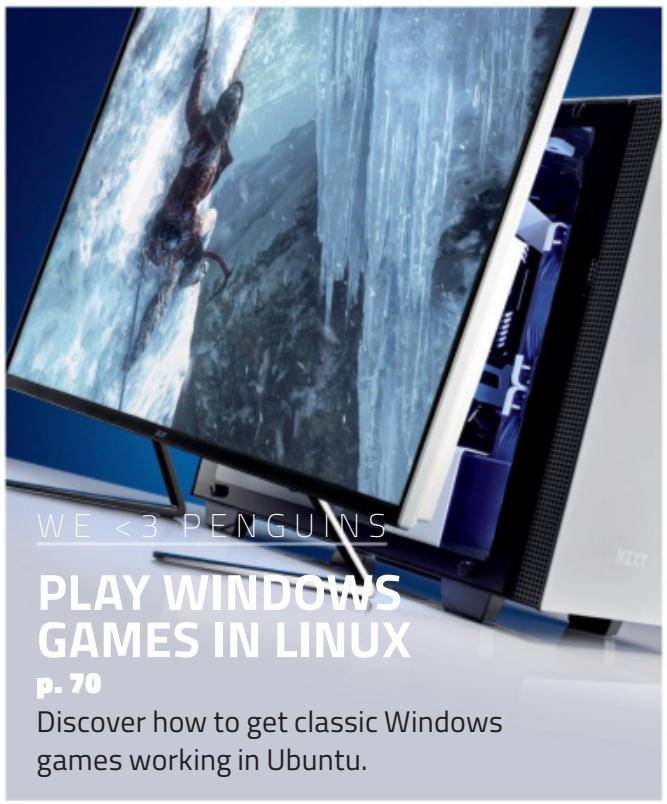

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KNOWLEDGE IS POWER

The above may sound like a tired old phrase, but the reason it has prevailed is that it is very, very true. With applied knowledge you can do a lot, and that is just as true whether you're an engineer, a physicist, or...

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So read on, learn, and make the most of your newfound skills.

David Hollingworth
Editor
@CptHollingworth

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AUSTRALIA'S #1 PC GAMING MAG
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SAMSUNG'S NEW 970 EVO PLUS SSDS TOUT FASTER SPEEDS AT LOWER PRICES THAN 970 PRO

For all intents and purposes, this is Samsung's new flagship SSD series.

Samsung today responded with its new 970 Evo Plus line of SSDs, which on paper is its fastest consumer NVMe offering to date.

It's somewhat of a surprise release, and an interesting one when you compare the specs to Samsung's 970 Pro family. Samsung has always saved its best performance for its Pro family, while its Evo drives have traditionally offered better pricing at slower (though not 'slow') speeds.

In this case, however, the upgraded 970 Evo Plus drives are rated to deliver sequential read speeds of up to 3,500MB/s, and sequential write speeds of up to 3,300MB/s.

The sequential read ceiling is the same as the 970 Evo (non-Plus), but the 3,300MB/s write ceiling is significantly faster than the 2,500MB/s of the non-Plus family. Speeds vary by capacity, but here's how the rated performance compares at the top end of each SSD family:

- Samsung 970 Pro Evo: 3,500MB/s seq. read, 3,300MB/s seq. write
- Samsung 970 Pro: 3,500MB/s seq. read, 2,700MB/s seq. write
- Samsung 970 Evo: 3,500MB/s seq. read, 2,500MB/s seq. write

"Since introducing the first NVMe SSDs to the consumer market in 2015, Samsung has continued to challenge technical barriers in SSD design and performance," said Dr. Mike Mang, vice president of Brand Product Marketing, Memory Business at Samsung Electronics. "The new 970 Evo Plus powered by Samsung's latest fifth-generation V-NAND technology will now offer unrivaled performance in its class when taking on demanding tasks like 4K content editing, 3D modeling and simulation as well as heavy gaming."

For this new series, Samsung is using 96-layer 3D NAND flash memory chips, which is the fifth generation of 3D NAND, and an upgrade over the 64-layer 3D NAND that is found on the 970 Evo.

AMD VOWS TO HAVE RADEON VII LINUX DRIVERS AVAILABLE ON DAY ONE

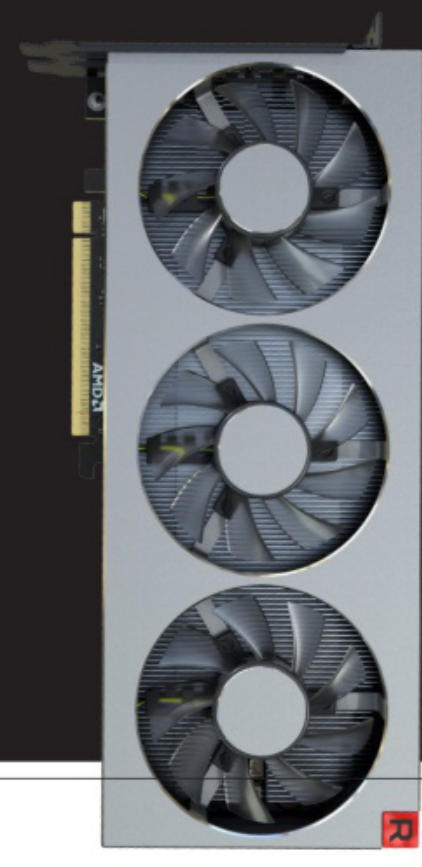
Good news for Linux users.

AMD's Radeon VII graphics card launches this month, and it will arrive with both Windows and Linux drivers from day one.

The former is a given whenever AMD (or Nvidia) launches a new graphics cards, though Linux drivers sometimes lag behind. A recent example is the Radeon RX 590. As Phoronix lamented, it didn't play nice on Linux at launch, and it took a few weeks before it finally did.

That shouldn't be the case when the Radeon VII launches. Jason Evangehlo, a former marketing specialist for AMD's Radeon division, wrote on Forbes that he reached out AMD's PR people over the weekend and asked if the Radeon VII would be "gaming ready on day one right out of the box."

The answer was an "emphatic 'yes'," Jason says. That means Linux driver availability and presumably proper testing beforehand to ensure it works better than the Radeon RX 590 did at launch.



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NVIDIA IS RUMORED TO BE READYING A GEFORCE GTX 1660 TI GRAPHICS CARD

It would be for gamers who don't want to pay a premium for ray tracing.

Supposedly three industry sources squawked to Videocardz about the upcoming card, at least one of which is purportedly a board partner. It might end up with a different model name, but the takeaway is that it will be the first Turing-based card under the GTX brand.

As the story goes, it will feature a TU116 GPU with 1,536 CUDA cores and 6GB of GDDR6 memory on a 192-bit bus. For reference, a GeForce RTX 2060 features 1,920 CUDA cores, along with the same memory configuration.

If those specs are true (and the card actually comes to fruition), it would likely perform in the neighborhood of a GeForce GTX 1070. The 1070 has more CUDA cores (1,920), but Turing is a faster architecture.

An interesting side note to all this is that Nvidia is phasing out its Pascal lineup. During a recent Q&A session with VentureBeat, Nvidia CEO Jensen Huang said that the GeForce GTX 1080 Ti, 1080, 1070 Ti, and 1070 have all sold out, and "in several more weeks 1060s will sell out."

ASUS BUILT A CASE WITH VERTICAL EXPANSION SLOTS TO SHOW OFF YOUR GRAPHICS CARD

A future version might also incorporate a built-in OLED display.

It seems Asus is increasingly interested in computer cases these days and is making a spirited run at the product category. Its newest model—and only its second standalone case in over a decade—is the ROG Strix Helios that was teased at CES. It now has a product page.

Unlike the version that was shown off at CES, there is no OLED display embedded into the front panel. Apparently Asus was only toying with the concept, though it could reemerge at a future date on a special edition.

Asus classifies the ROG Strix Helios as a mid-tower. It has 10 expansion slots, though two of them sit vertically so you can display your graphics card in the same orientation. It's not clear if Asus will bundle a PCIe riser cable or not.

For storage, there are four internal 2.5-inch drive bays, and two more that can accommodate both 3.5-inch and 2.5-inch drives.

The case comes with three 140mm fans in the front and another one in the rear. There's room for two more up top, or three 120mm fans if you prefer. If you're going the liquid cooling route, you can fit up to a 420mm radiator up front, up to a 360mm radiator up top, and up to a 140mm radiator in the rear.

Where Asus goes from here is anyone's guess. As for the ROG Strix Helios, the company has not yet announced a price or said when it will be available to buy.

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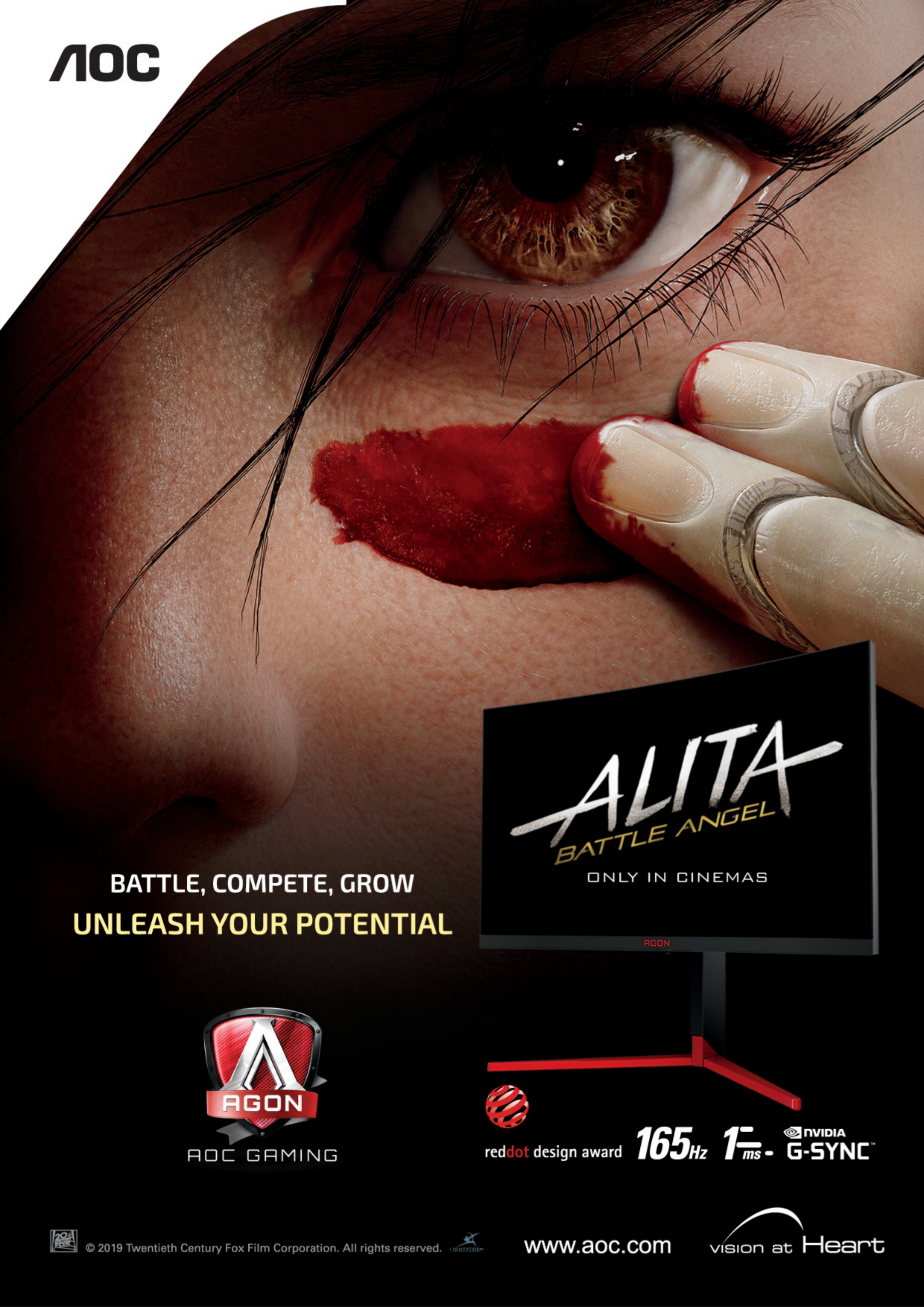

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BATTLEFIELD 5 MAY NOT GET RENTAL SERVERS

Electronic Arts hasn't decided yet whether it will offer a rental server program for the newest Battlefield.

Battlefield's server rental program gives players the ability to operate their own game servers, with map rotations, game modes, and gameplay settings customisable as the renter sees fit. Third-party companies operated the servers for earlier Battlefield games, but EA assumed exclusive control with Battlefield 1. It said during a September livestream that rental servers would not be available at launch, which caused some concern, but the general assumption seemed to be that they'd come along sooner or later, since previous Battlefield games also launched before rental servers were ready.

But a message posted on Reddit by Battlefield global community manager Dan Mitre suggests that it might not happen at all. "You haven't seen an update in our direction with RSP [Rental Server Program] because we haven't made a full decision internally whether or not we can deliver it," he wrote.

"RSP needs to meet standards and your expectations with the tools we provide—that takes development resources. It also needs to make economical development sense—we can't introduce a feature that ends up costing more to keep maintained than it returns (I know that statement will open up more debate, and I encourage that, but this is the reality of the situation). In other words, we don't want to impact development resources of main game Quality of Life commitment and upcoming content by routing team bandwidth to RSP development. There's also financial implications here that go well beyond my remit."

FARMING SIMULATOR GOES ESPORTS WITH A €250,000 PRO LEAGUE

The Farming Simulator League will feature ten events including 3v3 competition in a new game mode.

I like to poke a little fun at the Farming Simulator games now and then, mainly as an excuse to link to this, but the reality is that it's a big and remarkably durable fish in the niche simulator pond. So big, in fact, that developer Giants Software is launching a Farming Simulator League, which is a competitive pro league with a €250,000 prize pool, and no, I am not joking.

Believe it or not, there were four competitive Farming Simulator tournaments held in 2018, in Switzerland, Germany, and Poland. But they were one-off affairs with relatively tiny prize pools—the biggest was at Herofest 18 in Bern, which offered a prize pool of €2890. This new endeavor will be "a full-fledged esports league with 10 tournaments across Europe," and real cash on the table.

Each event in the tournament series will offer prizes and circuit points that will take the best teams into a €100,000 grand finale. Giants has partnered with Logitech, Intel, and noblechairs for the new pro league, and will work with service provider Nitrado for hosting and streaming. Tournament games will run in Farming Simulator 19, and will expand from bale stacking to "a competitive 3v3 mode where teams will challenge each other to determine who is the best on the field."

18+

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Identify bottlenecks and break through into pro-grade benchmarking.

2019 TECH PREVIEW

Take your mind back a moment. It's November 1996, Bill Clinton has just beaten Bob Dole to the presidency, "Macarena" is topping the charts, and Star Trek: First Contact is about to make waves at the box office. In the world of tech, however, something more wonderful is about to happen. Andrew Grove, Intel's CEO of the day, is about to drop one of his truth bombs, and that truth? Well, it's that by 2011, thanks to a combination of Moore's Law and genius architectural advancements, Intel CPUs will be operating at the 10GHz mark and beyond.

Although that prediction may have fallen a bit flat over the years, it's not to say we haven't advanced since then, technologically at least. The world of the transistor stops for no nerd, and as another orbit of the sun comes to a close, it's time for us here at the PCPP Lab to condense all of our prophetic ability into one clean, crisp, potentially slightly wooly, article. So, folks, likely more accurate than your election-time pollsters, and definitely more truthful than those Hurricane Florence weather forecasts, hold on to your hats, because it's time for PC PowerPlay's Tech Preview 2019.

ZAK STOREY & JEREMY LAIRD

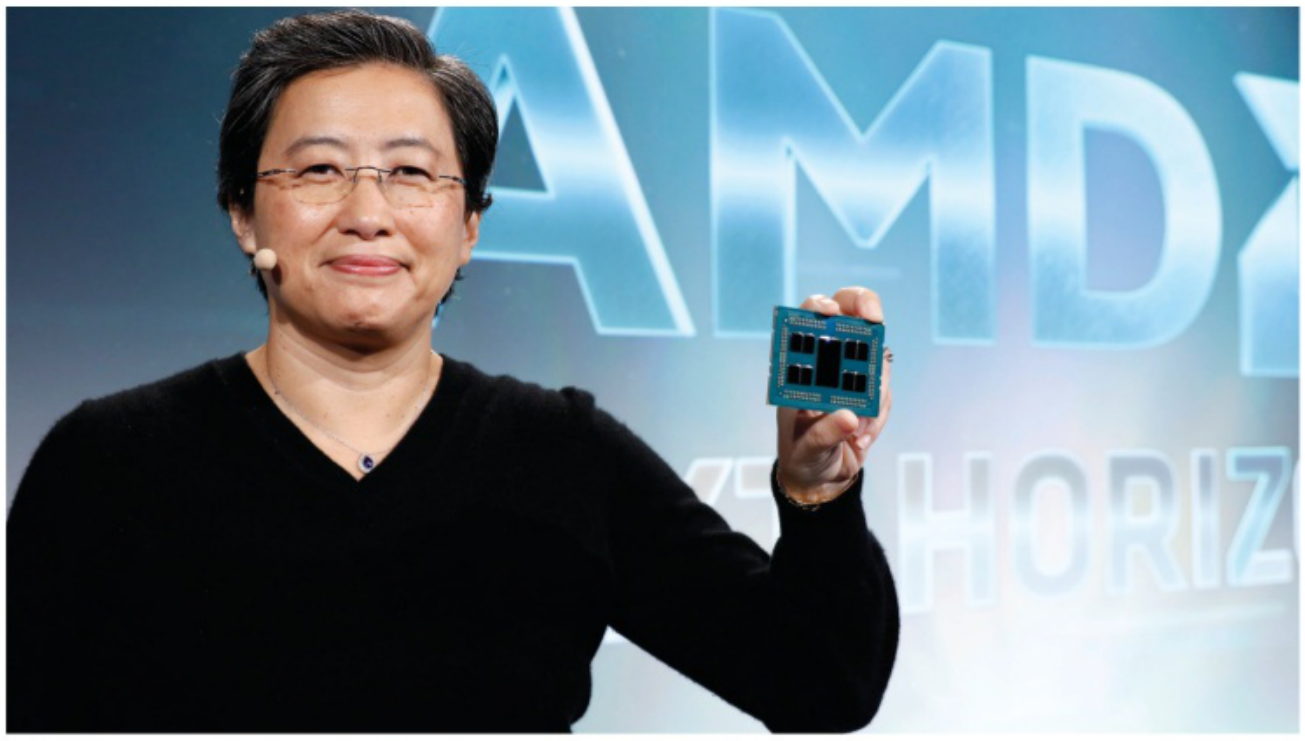
The battle for processing superiority

What does the future of high-end tell us about the destiny of mainstream processing?

Nothing's better for the tech industry than a little competition, and that's something Ryzen has very much brought to the table over the last two years. Consider this: Since the beginning of 2017, we've doubled the number of cores available to mainstream processing parts. From the very bottom rung, with Pentium and Athlon CPUs, all the way up to the Core i9s and Ryzen 7s, Intel and AMD have produced an epic lineup of chips, with twice as many threads as before. Look at high-end desktop processors, and that figure has almost quadrupled. Crazy. In early 2017, Intel's 10-core Core i7-6950X would set you back US$1,723; today, you can buy AMD's TR 2990WX, with an incredible 32 cores, for just US$6 more.

Are we likely to stop here? We doubt it. With AMD announcing its EPYC 2, Rome, server processors, due to launch in the second quarter of this year, the core war is still very much in full flow. Packing 64 cores and 128 threads on a single processor, with a far superior memory interface design than previously, supporting PCIe 4.0, and on TSMC's 7nm manufacturing process, AMD's next-generation server parts look as though they're going to be phenomenal computational monsters. There are even rumors of a 29.4 percent performance increase in single-core IPC, all down to architectural advancements and floating point calculation optimizations, rather than simply increased clock speed and voltage.

EPYC 2 is important for a number of reasons. Firstly, because it runs off the successor to the ridiculously good Zen architecture, the 7nm Zen 2, which will also be found in the third-generation Ryzen parts (also due this year). And secondly, as the first-gen Threadripper processors were essentially cut-down variants of the first EPYC server parts, it gives a good guess as to what Threadripper 3 might look like, too.

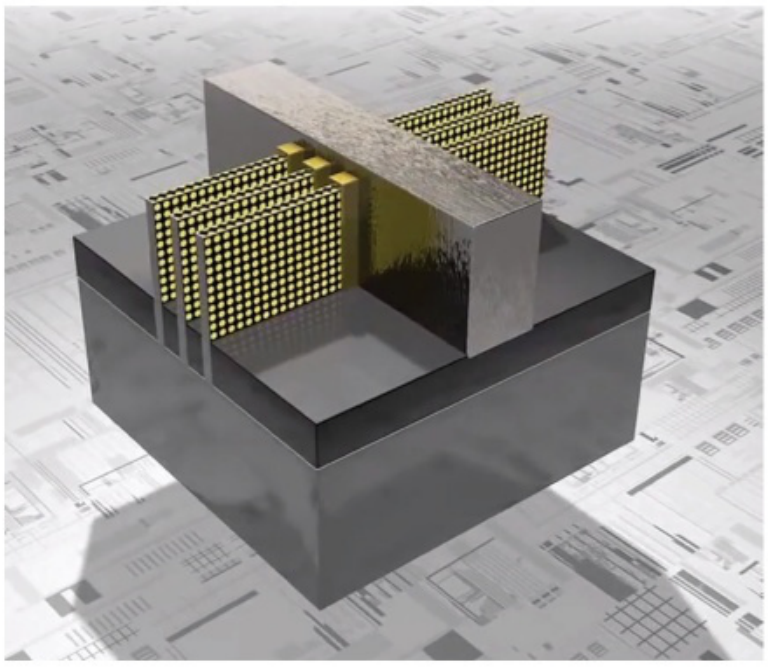


▲ **Welcome to Rome!**

The big question is: What's going to transpose down? Apart from eight-channel memory and the PCIe 4.0 enhancements, which we're hoping make it, what will be more intriguing is how many cores are brought along with it. We imagine AMD will likely keep the overall design of the two SKUs the same, to help reduce manufacturing costs, but as we've already seen 32 cores on the mainstream Threadripper platform, it does leave questions as to how many cores will make the jump. At a guess, we may see a high-end 3995WX, likely the same price as Intel's unreleased 28-core HEDT part, potentially touting 48 cores and 96 threads, for the true amateur renderers and CAD-CAMmers.

We also know this is the first time AMD's deviating away from a single-size transistor design across the chip. Thanks to its Infinity Fabric, the company will be going to a modular transistor size architecture design, with things such as the ridiculously fat I/O controller staying on 14nm, while the main core complexes will be on 7nm.

Hopefully, most of that should filter down to Ryzen 3. We'd love to see a 16-core Ryzen 7 3700X, with support for PCIe 4.0, and perhaps more PCIe lanes in general for better PCIe SSD support, hooked up in a similar manner to its Threadripper kin—16 for GPUs, and an additional eight for PCIe storage would be a fantastic solution, and really future-proof you as PCIe SSDs break that 3.2GB/s barrier.



▲ A three-dimensional representation of a tri-gate 14nm transistor.

THE QUEST FOR 10NM

If the reported figures are correct, and AMD's samples of the EPYC server parts prove as mighty as they currently are, Intel may lose the top spot in multi and single-threaded applications. That would be the first time since the early Athlon days that Intel has lost its grip on the top spot of processing performance.

It all rests on whether Intel can hit its 10nm volume production targets in its current timeline. Although originally outlined to make it to market by 2016, delays and complications have lead to multiple refreshes of Team Blue's 14nm architectures, with its current roadmap suggesting the company should be able to make bank on its volume production targets by the second half of 2019, leading to a late fall release at the earliest. That said, there is one 10nm processor currently in existence: the Core i3-8121U. It's an ultra low-power mobile part by design, but in a rather bizarre twist, the integrated GPU is switched off. According to sources, this is due to logic incompatibilities between the GPU and CPU that are currently too troublesome to rectify.

Going from 14nm to 10nm should allow Intel to increase its transistor density by a factor of 2.7. However, as in the past, this likely won't lead to a huge performance increase, so far as IPC is concerned, and with no evidence or rumors on benchmark performance, we can't say how powerful these parts will be. All of this leaves AMD with eight to nine months of open market to capitalize on, if it can successfully get its 7nm processors out of the door in time.

THE FUTURE OF PROCESSORS

With all of this coming from the mainstream manufacturers, you might be forgiven for thinking that's it for the world of the humble processor. Well, there's one outlier you might not expect to be making waves, but there are more than just ripples coming from our long-misjudged technical brothers across the battle-ravaged OS ocean. Apple is seemingly picking up the pace when it comes to processor design and overall performance. Take a look at the ARM-based Bionic A12 X processor found in its latest tablets, and even in the iPhone XS, and you'll see performance numbers equal to a mid-clocked Sky Lake Core i5-6400 or so.

That might seem like small fry when you look at the current state of desktop processors, but given the fact that the company has been working on its own bionic processors for a little over six years, coupled with Intel's continued delays in hitting its transistor targets, and the big fruit might finally be making its way to forging its own processors to replace the Intel ones found within its consumer devices. This is further backed up by a report from Bloomberg, back in 2017, stating that Apple plans to replace Intel's processors inside its Mac lineup by 2020.

Given that the iPhone XR scores a hefty 4,793 points in GeekBench's single-core test, in comparison to an AMD Ryzen Threadripper's 4,801, it's not hard to see where this could go if Apple really pushes the boundaries of that ARM processing tech.

"Take a look at the ARM-based Bionic A12 X processor found in its latest tablets, and even in the iPhone XS, and you'll see performance numbers equal to a mid-clocked Sky Lake Core i5-6400 or so."

The graphics of tomorrow

AMD looks to the mid-range; Nvidia still holds the high ground.

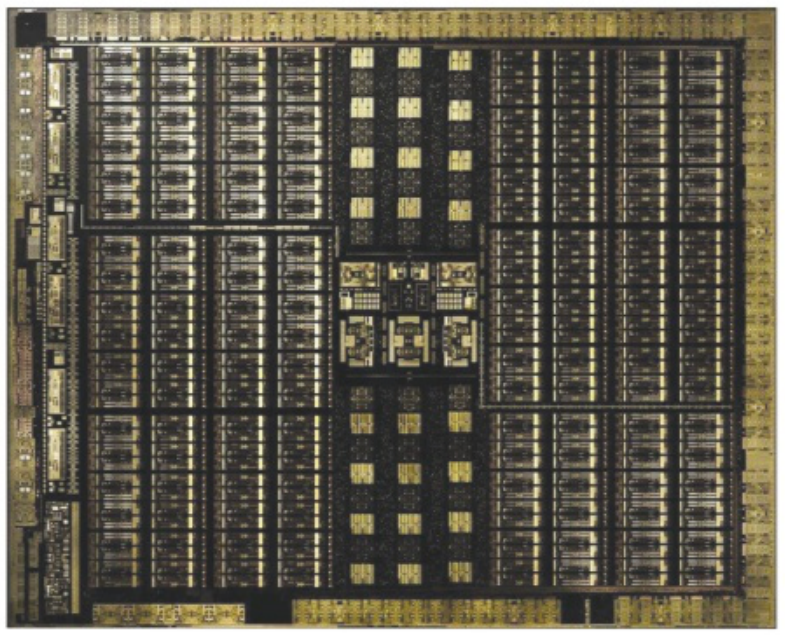
2018 may have seen the advent of ray-tracing for Nvidia, but Turing actually left a lot to be desired. The full-fat architecture provided a solid 30 percent performance increase, but as it cost over 70 percent more—thanks to the introduction of dedicated ray-tracing and DLSS hardware—that boost felt more than a little lackluster. New architecture designs and implementations always come with an increased cost to manufacture, but this was hard to swallow, especially with no titles upon which to test those features.

But all is not lost. Competition drives down prices, motivates innovation, and brings a better solution for all of us. It's all down to AMD. Navi is the name of the game, and we should be expecting this some time in the second half of 2019. This 7nm GPU will be manufactured by TSMC, the same company pumping out AMD's Zen 2 chips. We don't know a huge amount about Navi just yet, other than rumors circulating that it's being positioned as a mid-range GPU right now, as opposed to anything capable of taking on the high end. This is interesting, because if it does pack a big enough punch at the right price in the mid-range, it may very well pull down the pricing of Nvidia's other offerings at the top, as it reshuffles its entire arsenal to compensate. And as we know from experience, it's the mid-range cards that hold the most clout when it comes to profit and market share.

That said, even if AMD doesn't make a huge amount of bank in the world of the PC enthusiast, its Radeon brand is assuredly safe, thanks to its immense dominance in the world of console computing, and, boy, is that a big market to control. Does that mean this is the end of AMD at the high end? Probably. Can we expect Nvidia prices to keep climbing? Well, unless another manufacturer comes out with a complete curve ball in terms of how we render in-game graphics, it's looking likely that its dominance in this market is assured.

NVIDIA'S MID-RANGE STAKE

That said, we're still expecting a few releases from Nvidia some time this year: a Turing (or rebadged Pascal) variant of the RTX 2060, and we're seemingly still missing a Titan of some description, too, although we'd be surprised if that wasn't any less than $1,900, for one extra GB of GDDR6, a few CUDA cores, and some developer



▲ A full-fat Turing die.

▼ Could we see an RTX 1060 without the RTX heavyweight hardware?

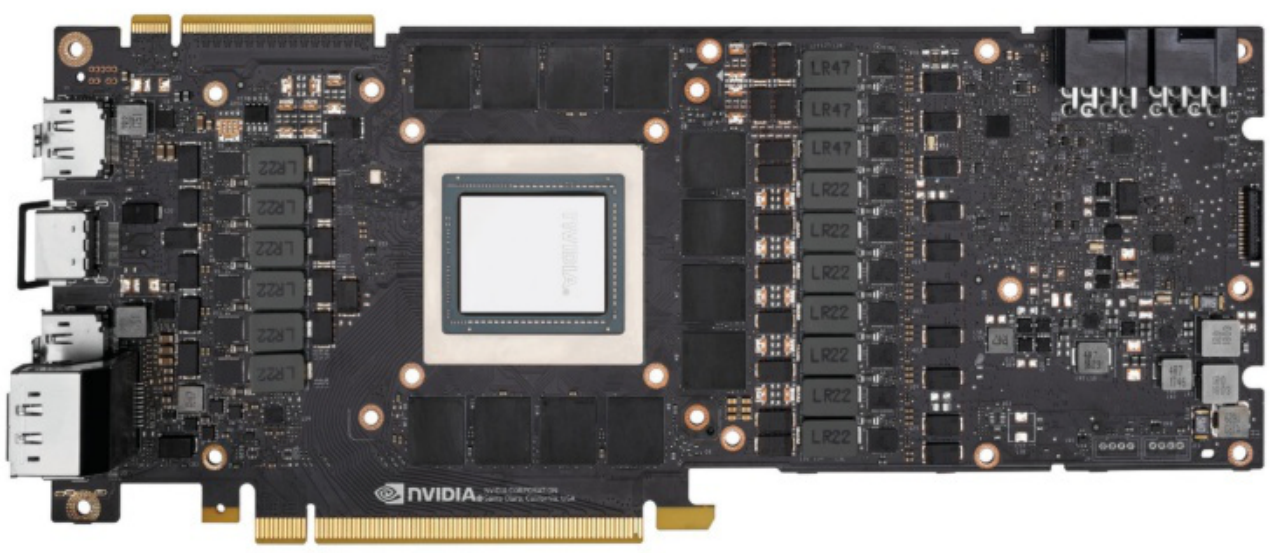
features. The 2060 is also of particular interest, and it'll mostly come down to the nomenclature Nvidia decides to use. If it's a GTX card, and Nvidia forsakes the RTX hardware (which would make the most sense, given its lackluster performance, even at 1080p, on the 2070), then it could be quite the impressive value card.

Spec-wise, we'd expect around 1,920 CUDA cores, and potentially either 8GB or 6GB of GDDR5X, as opposed to GDDR6. That should then perform quite nicely at around 60fps at 1440p. Although this is, of course, all speculative.

We've already seen some preliminary figures leaked online, most notably in Final Fantasy XV's benchmark, where a supposed RTX 2060 scored 2,589 points at 4K; in comparison, the GTX 1060 scored 1,985 points total. As expected, that's an increase of around 30 percent in performance.

Although this hasn't been confirmed officially, the card also retained its RTX nomenclature. If we did see RTX hardware make the cut, it'd likely be 24 RT cores and 192 Tensor cores—a little low for true ray-tracing or DLSS support. DLSS is arguably going to be more important at 1080p gaming than ray-tracing, but even so, there's still no word on price.

> "New architecture designs and implementations always come with an increased cost."



Storage solutions solidified

Intel and Samsung duke it out.

This time last year, we predicted the future of non-volatile memory, and therefore SSDs, would be all about Intel's 3D Xpoint and Samsung's Z-NAND technologies. Fast-forward 12 months, and not much has changed, including the fact that we're still largely talking about the future. Neither 3D Xpoint nor Z-NAND have yet made much impact in consumer-level PCs.

That said, Intel's 3D Xpoint tech has become more widely available. Multiple generations and formats of drives based on 3D Xpoint and sold under the Optane brand have been released. We've had first-gen PCIe boards and M.2 cache cards replaced by second-gen products, while larger M.2 SSDs with just about enough capacity to run as primary drives have also been released. You could even argue that the mighty Intel 905p PCIe board is a third-gen product.

While Intel has made much progress, including refining its Optane controllers and algorithms, and bringing prices down, a limitation remains: Intel is still using first-gen 3D Xpoint memory chips. What's more, the Intel and Micron venture that created 3D Xpoint is on borrowed time. The two will part ways toward the end of next year.

The companies say they will keep working together to release second-gen 3D Xpoint memory chips in the first half of 2019, following which their venture will be done. For now, almost nothing is known about that second-gen 3D Xpoint tech. But more capacity at a lower cost would address the main remaining reservation we have with Optane drives: They're so expensive.

As for Samsung's Z-NAND, we've yet to see one in our labs, and no consumer variants exist. Despite that, Samsung has announced a second generation of the tech. It includes new SLC Z-NAND that doubles the data density of its first Z-NAND chips to 128Gb, and a new MLC variant with a nifty 256Gb per chip. However, the first products based on this will still be pricey, with large drives aimed at enterprise applications, as opposed to everyday consumers, a market shored up by its 3D NAND applications, and 970 Pro and Evo drives.

What's also unclear is the extent to which Samsung's Z-NAND is protected by patents. Toshiba's upcoming XL-Flash promises a very similar set of advantages as Z-NAND, including 10 times lower read latency than NAND. The overarching point involves competition. While Z-NAND and XL-Flash don't offer the same latency advantages as 3D Xpoint, they do promise to keep Intel on its toes.

How all that maps to SSDs isn't entirely clear. However, SSD prices are at an all-time low going in to 2019, and with QLC or quad-level NAND flash ramping up, large drives are only going to get cheaper. Will we see the first sub-$100 1TB SSD from a big brand in 2019? Maybe. At the same time, second-gen 3D Xpoint memory chips, plus wider adoption of Samsung's Z-NAND and perhaps Toshiba's XL-Flash, should enable a new generation of lower cost ultra-high performance SSDs. They still won't be cheap, but it's not hard to imagine a setup with something like a 250GB Optane OS drive and a 1TB SSD for mass storage being affordable by the end of the year. For most PC enthusiasts, however, 2019 will be about conventional NAND SSDs becoming cheaper than ever.

THE FUTURE OF DRAM

This could be the year we see the first DDR5 memory kits make it to market. We saw Micron and Cadence demo working DDR5 memory in late 2018, and even with JEDEC not finalizing the spec just yet, manufacturers are expecting to begin production in the latter half of 2019.

When it comes to DDR5, although it looks to be more of the same, it couldn't be further from the truth. Expect MT/s (MHz for the marketing gurus out there) to start at speeds of 4,266MT/s and reach 6,400MT/s, followed by a drop in voltage from 1.2V down to 1.1V, and a doubling in maximum capacity per chip, as usual.

According to Cadence and Micron, however, all that is just icing on the cake. The big changes will be at an architectural design level. Thanks to an improved command bus efficiency, superior refresh structures, and more bank groups being available to the processor, end users can expect nearly a 30 percent performance increase in real-world bandwidth, and that's just when comparing two identically clocked DDR4 and DDR5 kits together. Take a 3,200MT/s kit and compare it to a DDR5 4,800MT/s kit, and you could be looking at nearly 80 percent overall bandwidth improvements.

This is likely to hit servers at the end of 2019, with desktop applications ramping up mid-to-late 2020. It's possible, given AMD's release schedule, that we could see this launch with the Zen 3 architecture, as it will require a new socket, and as Zen 2's EPYC processors will be backward compatible with current sockets, it's unlikely Threadripper 3 and Ryzen 3 will require new sockets as well.

SIX OR EIGHT CHANNELS?

DDR5 might not be on the cards until 2020, so is there anything we could see in the meantime to bolster memory performance? The most obvious solution would be an increase in the number of memory channels accessible by high-end desktop users, as that's typically where memory matters most. Mainstream platforms can get away with dual-channel and DDR4 for some time, but for the high-end, any increase in memory bandwidth bolsters performance in ray tracing, video rendering, CAD CAM, you name it.

AMD is likely to be unwilling to introduce more channels on its high-end motherboards just yet, because apart from including support in its latest Threadripper processor designs, it would also need to redesign its LGA socket on motherboards, so the newer chips would cease to be backward compatible with current X399 mobos.

That said, there is a small chance that AMD could pull the trigger on that sooner than we think, depending on what Team Blue does. We've known since August that Intel intends to launch a 28-core unlocked Xeon on its high-end consumer platforms soon. This 14nm 28-core, 56-threaded beast comes on a new chipset (X599), with a new socket (LGA 3647). It requires a boatload of power, and one hell of a VRM solution to compensate, but more importantly (because of its Xeon heritage), it includes a six-channel memory solution. There's proof of this already in Asus's ROG Dominus, as it packs 12 DDR4 DIMM slots, alongside two custom M.2 DDR3-style DIMMs. On top of that, the board requires four eight-pin EPS power connectors, dual six-pin 12V connectors, and dual 24-pin ATX mobo power. And did we mention it has an actively cooled 32-phase VRM design as well? Crazy.

That six-channel memory support is the first of its kind, and if the board and chip sell well before AMD's Threadripper 3 series arrives, the Threadripper 4 refresh may bring with it the eight-channel memory support found on its EPYC and EPYC 2 server-grade brothers.

What does it mean for end users? Well, if we take a dual-channel memory kit at 3,200MT/s, the total bandwidth is 51.2GB/s, quad-channel doubles that to 102.4GB/s, six-channel gives 153.6GB/s, and AMD's eight-channel memory would give 204.8GB/s, ideal for transferring large data sets or raw footage.

Interface Connection Advancements

Where will the world of interconnectivity take us?

Rumors abound that PCIe 4.0 is coming to the masses. Perhaps not in the early part of the new year, but you can bet it'll be here by the end of 2019. Announced in 2016, and ratified by PCI-SIG (a super-conglomerate of over 900 companies, including Intel, AMD, Dell, HP, and IBM) in the summer of 2017, PCIe 4.0 should have already been in production and on mainstream boards sometime in 2018. However, with a lack of support on the processor side of things, and there seemingly not being a need for the connection standard, delayed implementation and progress on introducing the spec has stagnated. We just didn't need it. Until now.

If Threadripper and Ryzen 3 follow the same or a similar specification as that of EPYC 2, both processor lineups should see support for PCIe 4.0 included as standard, with Intel also likely to follow suit with its 10nm parts. And with it being backward compatible, not including it on the next generation of motherboards would simply be ridiculous.

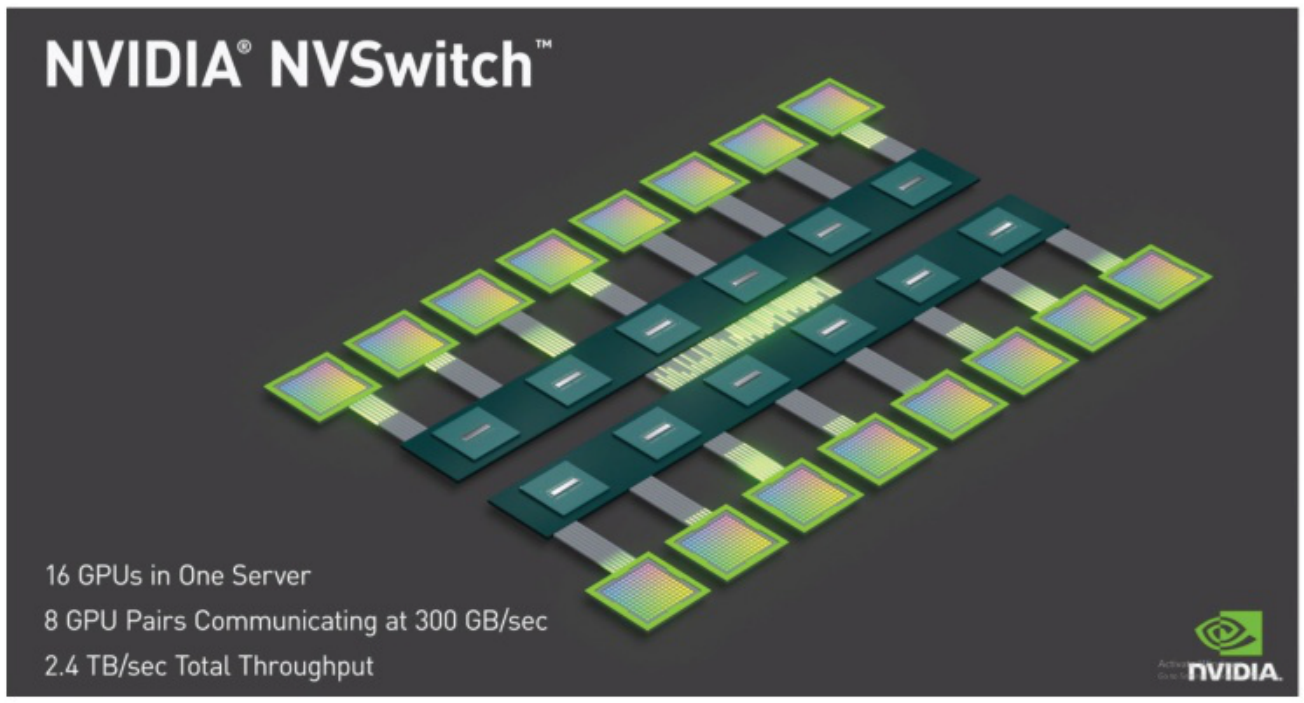
What's so great about PCIe 4.0? For starters, it doubles the per-pin raw bitrate, increasing from 8GT/s to 16GT/s. It also comes packing a reduction in overall system latency, along with improved flexibility and lane-width configurations for developers who are interested in tapping it up for lower-power applications and devices.

The big one for us, however, is that increased data rate. 16GT/s per lane should enable PCIe x4 devices to operate at up to speeds of about 6.4GB/s, versus the 3.2GB/s cap we're at now, giving us a lot more headroom for flash storage devices, and hopefully improving CPU-GPU communication and performance in multi-card situations, especially at higher resolutions. The latter is less of a problem for Nvidia, with its NVLink, of course, but for AMD, it's a pretty big deal, especially if the company gets back into the high-end GPU game with Navi.

PCI-SIG has also teased us with PCIe 5.0. Although complete specifications are sparse right now, we do know that it will be another doubling of the bandwidth limitations, meaning 32GT/s per lane, or 12.8GB/s theoretical maximum for transfer speeds on flash devices, and a staggering 128GB/s bandwidth for something like a 16-slot GPU.

The big question is how will these standards be introduced—if at all? Opinion in the office is split. The first camp, rooting for PCIe 4.0, reckons that thanks to EPYC 2's integration of PCIe 4.0, it wouldn't make a ton of sense to develop and assemble two separate processor designs, when you could produce one and disable some of the cores. Thus, as PCIe 4.0 is backward compatible with the other

"If Threadripper and Ryzen 3 follow the same or a similar specification as that of EPYC 2, both processor lineups should see support for PCIe 4.0 included as standard."



generations, adding it is a fairly easy task.

The other camp, the skippers, reckons that the bandwidth provided by PCIe 4.0 simply isn't enough, and because it takes both time and money to validate a spec like this (bear in mind that PCIe 5.0 has already been announced, and is due for launch in 2020), why bother, when we'll just need to do the same again in 2021? It's a tricky one, and only time will tell.

NVLINK INNOVATIONS

AMD might well have finished with high-bandwidth multi-GPU interconnects, but because the company isn't currently inhabiting the high end of the graphics world, it's easy enough to understand why it would think that they are unnecessary. Nvidia, on the other hand… Well, that's a whole different ball game.

▲ **NVLink surpasses the world of the PCIe barrier.**

Although the RTX series has come with many caveats, when it comes to both price and support for as-yet unreleased and unproven game development features, one thing that is true is the ridiculous amount of data those cards can pump out at any one time. The RTX 2080 Ti, in particular, can push over 150fps in some 1080p titles alone at max settings.

When running multiples of these cards, particularly in more extreme workstation environments, having a way of transferring data across the cards simultaneously is pivotal when trying to maximize performance. And that's exactly where NVLink originated: the server environment.

In short, NVLink is a proprietary standard developed by Nvidia, which debuted back with the launch of its Pascal architecture, although the variant we know today was first seen with the Tesla V100 GPUs found inside the DGX-1 server. Each NVLink connection supports up to 50GB/s transfer rate (25GB/s each way simultaneously), well over 10 times what a single PCIe 3.0 channel can transfer, allowing for fast and seamless data throughput between the cards. The V100 cards supported up to six NVLink connections for a maximum transfer rate of 300GB/s

When it comes to mainstream cards, the RTX 2080 Ti supports two NVLink connections for a total of 100GB/s, while the RTX 2080 supports only one, for 50GB/s. Unlike SLI, NVLink doesn't act as a display interface, merging video outputs together like a scheduler, then back through the GPU-out. Instead, thanks to its super-low latency and high bandwidth, it allows multiple GPUs to pool their resources together as a shared entity, and communicate across the bridge, reducing traffic through the PCIe bus below, making the cards more efficient.

It's difficult to say just how much of an impact this will have on the gaming scene right now, but Hothardware.com suggests that in Shadow of War, at 1440p, there's as much as a doubling of performance when using NVLink versus traditional SLI, so far as scaling is concerned. PC

▼ **PCIe 3.0 may finally be on its way out.**

USB 3.2 AND THE TYPE C STANDARD

This will likely come as no surprise, but 2019 should see the advent of a lot more USB C-compatible devices, from monitors to GPUs, mass storage solutions, and eventually even peripherals. USB Type C will be the dominating form factor going forward, mostly due to its spec and form factor. Reversible by design, and secure-fitting, USB C cables are much easier to use than their USB Type A counterparts. Couple that with it supporting MHL, Thunderbolt 3, HDMI 1.4b, and DisplayPort 1.4 standards as well, and it starts to look like a winner. The biggy, however, is going to come with the introduction of the USB 3.2 specification. Ratified in early 2017, and still retaining its backward compatibility, USB 3.2 should see a doubling in total bandwidth, from around 10Gbps to 20Gbps (or 2.5GB/s).That said, there is a small chance that AMD could pull the trigger on that sooner than we think, depending on what Team Blue does. We've known since August that Intel intends to launch a 28-core unlocked Xeon on its high-end consumer platforms soon. This 14nm 28-core, 56-threaded beast comes on a new chipset (X599), with a new s

Builder's Bible

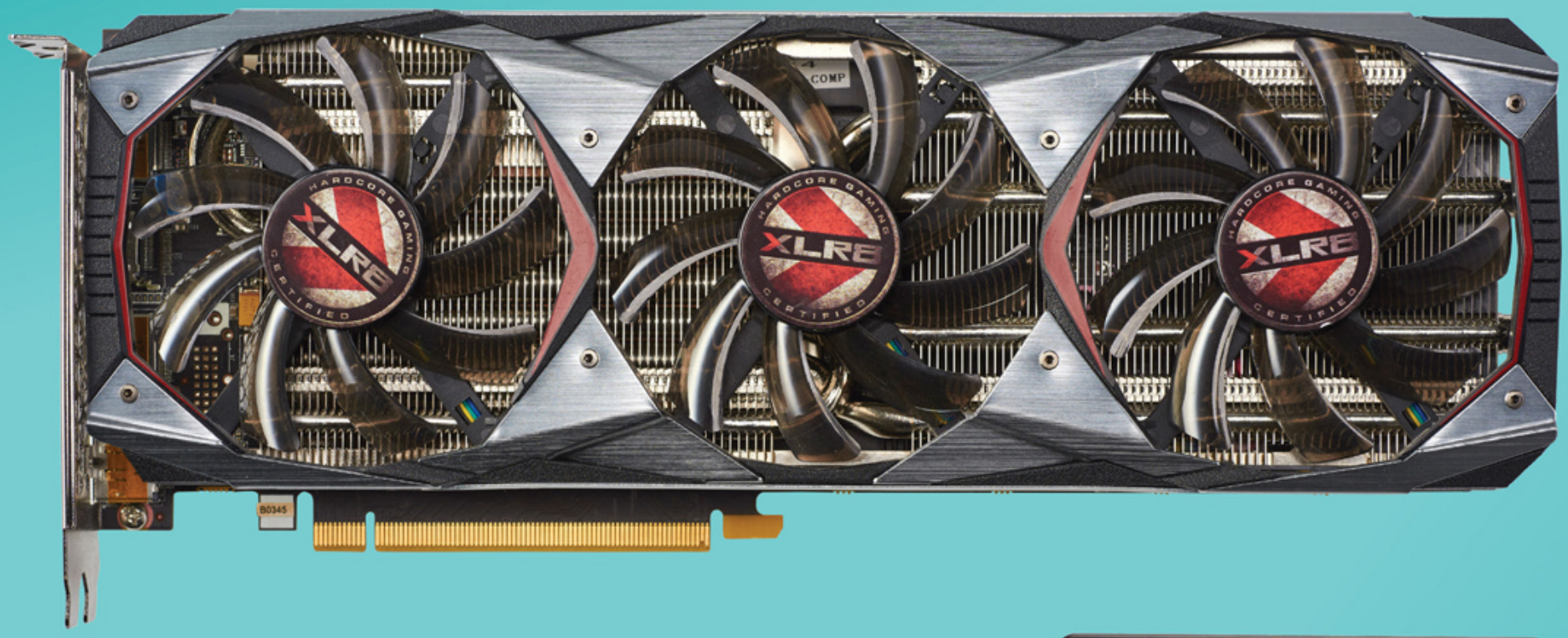
Top tips and tricks to make every build as easy as can be. Dodge common pitfalls, fix troublesome boot conundrums, and enjoy every minute of your DIY system-building experience.

System building is one of the central tenets of the PC enthusiast and gaming communities. It's something we should all aspire to. Here at PC PowerPlay, we've built rigs and taught others how to craft their own, both in person and across these pages, countless times. And with one very good reason: you get a real sense of pride from constructing your own machine, and an even greater one from teaching others how to do it. And with the added benefits of knowing every part that goes into your build, saving some cash, and understanding how to troubleshoot your system if it goes wrong, it's hard to ignore the advantages that system building brings.

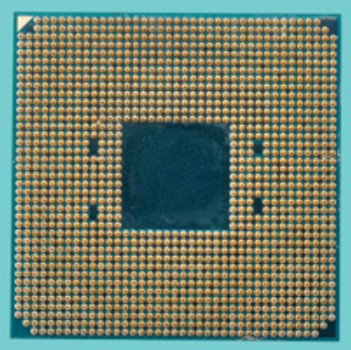
A lot revolves around system building across the industry. From hardware development, to the custom modding scene, to the liquid-cooling community, gamers, the video-editors, overclockers, Linux users, web developers, you name it—all of them are based around that one basic principle. And for many, it's what brought them to this community to begin with.

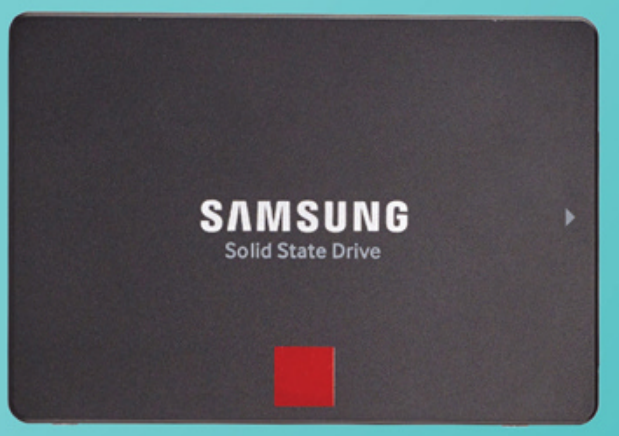
Yet in today's age of easy-to-construct behemoths, is there really that much hidden knowledge to be discovered when it comes to these builds? Well, from the budding builder to the artisan crafter, a little knowledge can go a long way, and even today, some of us beaten-up builders can still learn a thing or two whenever we step foot into each issue's "Build It" feature. So, let us impart our knowledge to you. We've broken more cases, sheared off more flesh, and destroyed more hardware than you can possibly imagine. Allow us to divulge those secrets, and give you our very best tips and tricks for building your own slice of Dream Machine pie.

ZAK STOREY


HARDCORE GAMING
XLR8
CERTIFIED

AMD
AMD




SAMSUNG
Solid State Drive

SEAGATE
BARRACUDA
COMPUTE
12TB
BarraCuda Pro
ST12000DM0007
SN: ZCH04G3J
PN: 2GR116-300
FW: DN01
WWN: 5000C500A3D057B3
PSID: 6UMA78B262HJDAW9PDGUA965J2J991KL
+5V 0.82 A
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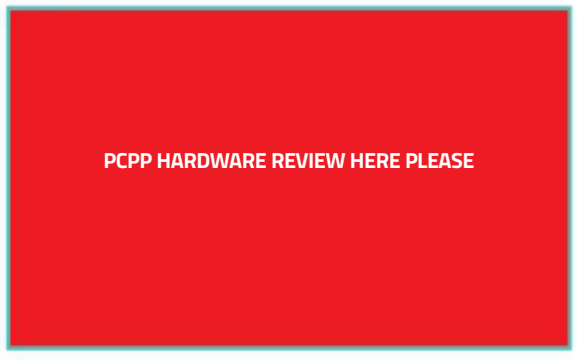
Site: TK
DOM: 18AUG2017
Product of Thailand
HDD Mfg by Seagate Technology LLC
Reg. Model: STL004
SATA AF
seagate.com

GODLIKE
ENTHUSIAST
GAMING
DDR4 BOOST
UNLIMITED
XTREME AUDIO DAC
M.2 SHIELD
CAUTION
msi

The perfect plan

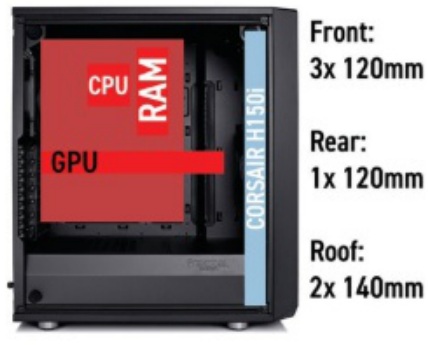
Research, plan, budget. Those are the first things you need to do when your mind wanders toward building a new rig.

TIP 1 RESEARCH



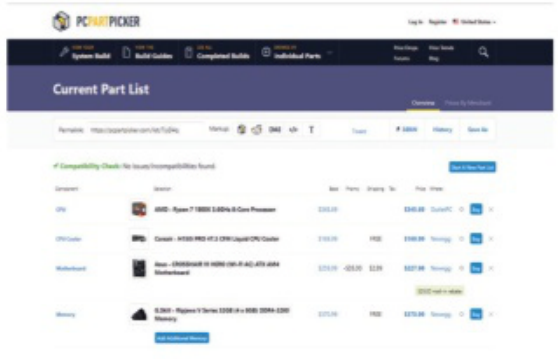
A little knowledge can go a long way when it comes to building your perfect PC. And the best place to start is reviews. You can look at all the build guides in the world, but if you don't know what gear is right for you, you're going to end up sorely out of pocket, and with a system not fit for purpose. Reviews are a huge source of information. Whether they're online, on YouTube, or in good old Maximum PC, you can learn how something works, how to install it, and how it performs when push comes to shove. Second to reviews are manufacturers' websites. Reading PDFs and install manuals ahead of time will make the build process far easier, and help you set everything up after, too.

TIP 2 PLAN



Next up is the planning phase. This is more of an environmental and aesthetic decision-making process than anything else. Figure out how much space you have for your new rig, where it's going to be situated, what form factor you want, and what chassis is right for you—remember, airflow and ambient temperatures are key. Then you've got to think about what hardware will fit where. Do you want a 240mm AIO up front? Will it conflict with your GPU? What will internal temps be like? Can you install it on the roof? Or perhaps an air cooler is better? All of these things can be answered long before you even take the first step into an online purchase.

TIP 3 BUDGETING



Taking the plunge and choosing what hardware is right for you relies heavily on the first two tips. Look at what cash you have and allocate it accordingly. Make sure you buy hardware that's either appropriate for what you do today, or what you will do tomorrow. Don't allocate half your budget to cooling and aesthetics if you can get 30 percent more performance out of it elsewhere. And make sure you don't waste cash (on faster memory kits for Intel, for instance) where you don't need to. If a sale is coming up, wait for it—they're usually worth it. Hell, you can drip feed hardware, too; buy one or two things per month, instead of going all-out in one go.

DIY VS. PRE-BUILT

We're in an odd place with pricing, and that old adage, "It's always cheaper to build your own rig," doesn't hold true right now, at least, not until Samsung and co. get their extra memory plants up and running. The memory shortage and cryptocurrency mining have ruined it for everyone. So how can system integrators still offer us cheap pre-built machines? It's down to pre-emptive bulk buying. Most companies that offer pre-built systems buy all the hardware they need in bulk, well ahead of time, so for the time being at least, they're still running off older prices, and can drastically undercut the current market.

Usually, the longer a memory standard has had to mature, the cheaper it becomes to produce, so the market stays ahead of the system integrators. But given current circumstances, that's just not possible.

That's not to say that system builders don't provide decent systems. Some of the best machines we've seen come from the likes of PC Casegear, Scorptech, and others. After all, when your livelihood revolves around building unique, bespoke, and powerful machines, you're going to learn a thing or two about putting together a stunning rig. Couple that with extensive parts and labor warranties, and they immediately become very attractive propositions, especially if you don't have the time or inclination to build your own.

Tools of the Trade

Nowadays, all you need to build most systems is a good old trusty Phillips head screwdriver, but here's a selection of the other frequently used tools and handy gadgets we turn to in our PC-building escapades.

MAGNETIC BOWL You can pick up this handy Park Tool magnetic bowl for a little under $20 from a range of places online. Amazingly useful for storing all your bolts and screws, you can attach it to anything metallic, at any angle, without the worry of losing any of the stuff inside. Plus, rub your screwdriver up against the bowl, and voila—magnetic screwdriver. That's *science*, folks.

ISOPROPYL ALCOHOL For less than $10, this is one of the few liquids that won't kill your hardware if it gets on it—99 percent alcohol is fantastic for cleaning off cruddy thermal paste, and is generally a good cleaning agent to get rid of smudges on almost anything (aluminum included). Just don't rub it on soft plastic stickers and the like. Or inhale it. Or get it on your skin. Or try to drink it. *Seriously*. Just be careful.

THERMAL PASTE We stick with one brand: Noctua's NT-H1 Thermal Compound. It's a non-conductive thermal paste, with a satisfying consistency, which doesn't spill out all over the place. You're not going to see revolutionary changes in temp with a higher quality paste, but you will see some. Just make sure you don't use conductive paste, but if you do, be careful when applying it to your CPU.

CABLE TIES Amazon will happily sell you 300 of these for about US$9, and they are, by far, the most useful PC building accessory you can own. Whether it's tying up spare cables, strapping cables to your frame, or jerry-rigging all sorts of mounting procedures for less-than-amiable products, the humble cable tie is clean, easy to use, and one of the most versatile tools on the planet.

SCREWDRIVER & SOCKET SET A decent set of screwdrivers will make builds far easier. Get a good kit with a variety of different sizes. Whether it's torque screws, tiny M.2 screws, standoffs, Allen screws, or even proprietary hex screws on the back of GPUs (here's looking at you Nvidia), a good set will cost you about $50, but potentially last a lifetime.

Chassis stripdown

So, you've bought all the hardware, your tools are prepped—what's the next step to ensure your build is as easy as it possibly can be?

TIP 1 CASE STRIPDOWN

The first thing to do (other than lay out all your hardware, and take a shot for Instagram, obviously), is strip your case down to its frame. Carefully unscrew, pop off, and remove every panel you can find. You can also remove the dust filters, and any hard drive cages you don't need. Doing this improves airflow, makes your build infinitely easier to manage in the early stages, and stops you manhandling and potentially damaging some of the more aesthetically pleasing panels (damn you, brushed aluminum).

TIP 2 PANEL STORAGE

It's smart to keep your part boxes, at least for a year or so, until the warranties run out. That said, there's an immediate use you can make of the box your chassis came in. The larger side panels and glass windows can slot carefully into your cardboard case box, between the polystyrene packing material, to ensure they don't get damaged or lost. You'll know where they are, and you can rest assured they're not going to fall over or get scratched during the build process.

TIP 3 MEDITATE

Not really, but you should visualise where your hardware is going to go. This is a great time to do a test fit—place your hardware where you think it'll go, and check there won't be any problems or conflicting parts. Imagine your cable routes, check there's enough room for your fans; it'll save time in the long run.

TIP 4 REPLACE THE STOCK FANS

Most stock fans are more than adequate for providing some sort of cooling, but if you have an eye for detail, you prefer more performance-oriented fans, or you're just after something that's a little quieter, replacing those stock polypropylene blades now is definitely the best decision. With unfettered access to every area at this point, it's easy to route the cables behind your case, and install them without worrying about the chassis being too heavy when everything's inside. One thing we would say is that you should wait until later to install any AIO liquid coolers, because the waterblock and tubing will only be a nuisance during the installation process otherwise. Also, if the top of the chassis is pretty tight, it might be worth holding off on those, at least until you've had the opportunity to plug in the motherboard power cables, and any other fan cables you're going to need.

TIP 5 PRE-THREAD YOUR CABLES

When working with more budget-oriented cases, with little cable management room, pre-installing and threading your cables ahead of time is a smart way of making a cleaner, tidier build, without necessarily breaking the bank. One particularly problematic cable tends to be the eight-pin EPS, or CPU power. For cases without any cable routing room, you can actually lay the CPU cable under the motherboard itself and into the top left-hand corner of the case. Then, after you install and secure your motherboard down (not forgetting the I/O plate, of course), you can plug in and install your CPU cable, keeping it out of the way and tidy in the process. In pricier options, and with modular power supplies, now is the perfect time to decide what cables you're going to need, and pre-install the lot, tying them to the back of the chassis where you can, using the cable ties we mentioned earlier.

Cooling mastery

Making sure your rig can handle the thermals thrown around inside is imperative, so how can you alleviate these conundrums ahead of time?

TIP 1 RIGHT FAN FOR THE RIGHT JOB

If you're looking at maximising your cooling efficiency, selecting the right fan for the right job is critical. There are two types of fan design: static pressure fans (with fat, thick blades), designed for high-pressure environments, where they need to push air through radiators or heatsink fins efficiently; and airflow fans (with multiple skinny blades), which are designed to move as much air through a system as quickly as possible, but without the same amount of force as their static pressure cousins. At the very high end, you'll find some static pressure fans that can shift as much air as an airflow fan, but that comes at a cost. Noise is also a factor. The bigger the fan, the slower the RPM usually, and the less noise. Typically speaking, if you're after a quiet rig, look for fans that operate below the 1,200rpm mark. You can control faster fans through the BIOS or a fan controller to go slower than the advertised speed, but you may encounter coil whine because of it.

TIP 2 COOLING WITH STYLE

With most mainstream, locked Intel processors, you can get away with the stock heatsink. If you prefer things more chilled, grab an aftermarket air tower. But there's nothing to say you can't use a 240mm AIO on a Core i3 or Ryzen 3. Any Intel K series processor at an i5 level, or Ryzen 5 or higher, should be cooled by a substantial tower solution or a minimum of 120mm liquid cooler. If you intend to overclock, this is a must. For Core i7 or Ryzen 7 and higher, with overclocking, use a 240mm AIO or high-end air tower. If you've not got much space, or limited intake, we recommend an air cooler over the all-in-one.

TIP 3 AIR PRESSURE

You've got the right fans and CPU cooling, so next up is internal case air pressure. There are two trains of thought: balanced and positive. Balanced means you're drawing (roughly) as much air in as you are pumping out, while a positive setup means you're drawing more air in than you're pumping out. Positive, in theory, stops dust entering through unfiltered areas, while a balanced system is better for airflow and temperatures. We're talking four or five degrees at most. Try both: using benchmarking tools, put your system under strain, read the resulting temperatures, and decide which you prefer.

TIP 4 FAN ORIENTATION

Fan orientation—we all slip up from time to time. So what's in, and what's out? In short, you can always identify the back of the fan (the area air is being pushed out of, as opposed to drawn into) as the part of the fan with the fan guard attached to it. If that doesn't help, it's the part that the fan cable typically comes out of.

ACCESSORISE YOUR COOLING

OK, we're talking about RGB. Why, when it's something we actively try to avoid? And how is it related to cooling? RGB fans are all the craze right now. We've seen plenty of LED fans in the past, but they typically only featured one color, and not the crazy cornucopia of rainbows that are now the norm across the industry.

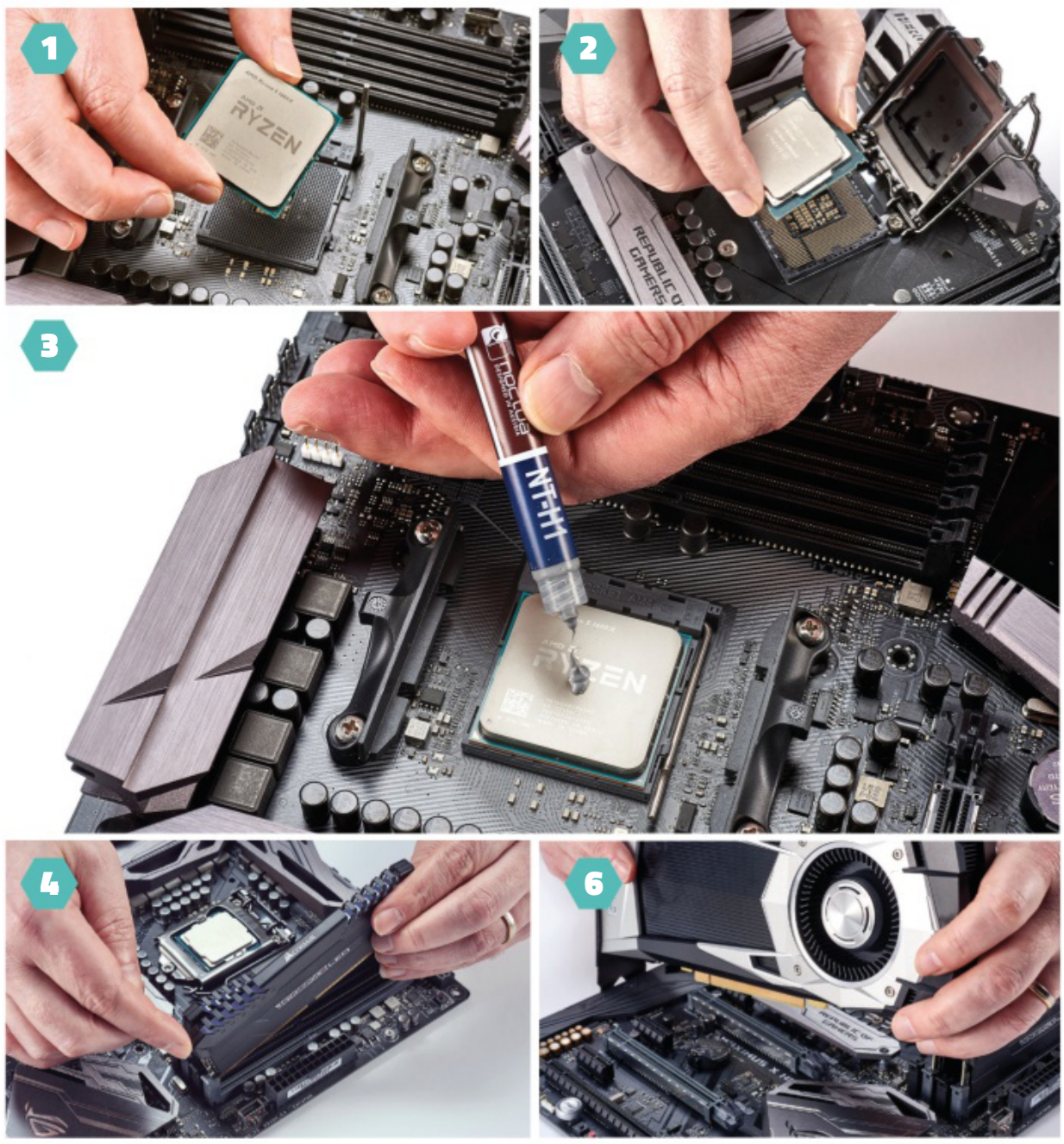
We get it: Some folks enjoy being able to light up their rig in all sorts of weird and wonderful ways. But when you're trying to do it with fans, you have to include an additional cable that connects elsewhere (either into a fan controller, an included RGB controller module, or directly on to the motherboard). That's another cable to route, and added bulk to work around the back of your rig.

It's something you need to take into consideration if you plan to invest in these things. As far as performance is concerned, there's a minimal impact on the fans. Admittedly, some blades do have to be constructed from a more transparent polymer, to allow the LED light shine through, but that's all there is to it. Static pressure, airflow variants—they're all there, albeit not to the standard of some of the more premium offerings.

If you're itching for both performance and the ability to take part in the RGB phenomenon, Phanteks will sell you an RGB fan frame (which, admittedly, even we think is cool). Known as the Halos series, they come in both aluminum and plastic variants, and light the blades up in a very smooth pattern, while remaining pretty classy in the process—however, they only fit 120mm or 140mm fans right now.

General build tips

Brushing up on the basics is a smart move from time to time—things change, methods adapt, and standards morph



TIP 1 AMD CPU INSTALLATION

Outside of Threadripper, AMD has stayed with the PGA (or pin-grid array) setup—the interconnect pins between the motherboard and CPU lie on the processor, as opposed to the mobo's socket, meaning fewer broken boards. To install your AM4 processor, match the golden corner on the chip with the corner on the socket. Lift the retention arm on the socket, carefully slot the processor into place, push it down firmly in the middle until it's secure, then bring down the retention arm to lock it into place.

TIP 2 INTEL CPU INSTALLATION

To install any LGA processor, lift the retention arm out and up, then lift up the bracket, leaving the protective plastic covering inside. Line up the processor's golden triangle with the etched triangle on the socket, gently drop it into place, then give it a tiny wiggle to make sure it's secure. Bring the socket bracket back down, securing it under the Torx screw, then bring the retention arm down, and lock it in place. The plastic cover pops off on any LGA 115X platform, but you need to give it a bit of a tug on the 2011 sockets.

TIP 3 THERMAL PASTE APPLICATION

If you're building a Ryzen or Coffee Lake system (or any mainstream CPU build), a small pea-sized dot of paste in the center of your CPU is all you need. If it's a larger processor—one of Intel's Extreme Editions, for instance—use two pea-sized dots, and three for Threadripper, down the center. This should be enough to ensure that any CPU heatsink, fan tower, all-in-one, or water block has sufficient thermal interface material to transfer heat away from the CPU die, across to the outer extremities of the heatsinks.

TIP 4 MEMORY INSTALLATION

Installing memory correctly is fairly straightforward. Find the notch on the bottom of each stick of memory, line that up with the notch in the memory slot on the motherboard, and carefully push it into place, making sure the clips on either edge of the memory slot are sticking up—these click into place once each stick is secure. Be sure to populate the color-coordinated memory slots, to ensure dual-channel or quad-channel support is operating correctly. If uncertain, refer to your mobo manual.

TIP 5 M.2 INSTALLATION

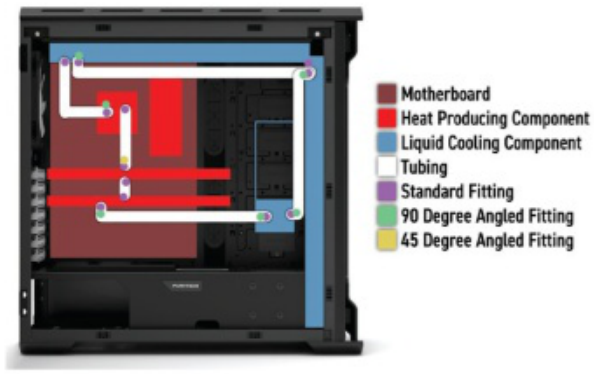
Installing the world's latest and greatest M.2 PCIe SSDs varies depending on which motherboard you're installing them on to. Some come with heatsinks, some don't. But the basic theory is pretty simple: Use a small screwdriver to unscrew the tiny Phillips screw that holds the M.2 down, line up the M.2 connector with the slot, and push it into place until it clicks in. Then line the end up with the mounting point at the other end, and secure back down with the tiny screw. You may have to move that mounting point depending on the length of your PCIe SSD, and there may be an additional heatsink you need to add before resecuring it (remember to remove the thermal pad's sticker first), but that's all there is to it.

TIP 6 PCIE INSTALLATION

When it comes to installing graphics cards and other add-in PCIe cards, first remove the rear PCIe covers from your case. Then, carefully line your card up with the PCIe slot on your motherboard, and gently push it into place until it clicks down. Make sure you install your GPU into the topmost PCIe slot for the best performance. There are different lengths of slot suitable for different purposes. PCIe x16 are the longest slots, designed for GPUs. You may find that some slots that look like PCIe x16 slots are actually x8 instead. You can decipher this by identifying whether the pins inside the slot go halfway or all the way to the end.

Advanced build tips

So, that's the basics dealt with, but what about some more advanced tips and tricks for the would-be liquid-cooler, the OCD-oriented cable tweaker, and the avid overclocker? Never fear—we have you covered



TIP 1 LIQUID PLANNING

A fully custom loop is something most PC builders aspire to at some stage. Whether you're keen to try it or not, knowing how to build one successfully is a key piece of knowledge to have. As with most builds, it all starts with a good plan, some acquired knowledge, and a touch of research. There are two basic principles to remember when liquid-cooling. Firstly, your pump must almost always be gravity fed by a reservoir, and secondly, each component you wish to cool must have at least 120mm of radiator to support it—more for overclocking. Once you've got that pinned down, it's on to the planning stage. Similar to our first plan we did back on page 28, it's a good idea to use a side-on image of your case, sketch out roughly where your CPU and GPU will be, and work from there. By that we mean decide where to place your radiators, reservoir, and pump (or pumps, if you're going for dual loops), then figure out how to run your tubing. Visualize your build, understand what direction the coolant will flow, then decide on your tubing runs. For beginners, we recommend keeping it as simple as you can at first, until you get the hang of it. If you intend to introduce a bend to your tubing, it's easier to work one into a long length than a short one, and it's always advisable to use angled fittings wherever possible, to reduce the number of bends you'll have to produce.

TIP 2 CABLE MANAGEMENT

Good cable management is all about layering. Identify what cables need to run where, then layer them. Most cases have more than enough room in the back to allow for cable management. Zip-tie bunches of them to the back of the motherboard tray, or use the Velcro straps often included in today's cases. Tie down your 24-pin and 8-pin CPU power first, then work on PCIe cables, and anything else afterward. Modular power supplies are a must—minimizing the number of cables you have keeps a build tidy.

TIP 3 PRO LIGHTING

Good lighting is hidden lighting. The aim is simple: Anything that produces light should be hidden, so you can only see the light that is thrown, as opposed to the light source itself. Hiding strips along the edges of cases, hidden by the thick black borders of tempered glass, or along the bottom of a chassis away from prying eyes, is a smart way of achieving this. On top of that, two strips are often better than one. Put one along the bottom and another along the front side, and you'll immediately light up two separate angles, producing a more dynamic lighting effect. Additionally, always go for a white light. Single-color strips (red, blue, green, and so on) typically drown out all definition and design on components. If a motherboard has red and black accents, and you throw a red LED strip in there, all you'll see is red everywhere.

CUSTOM LOOP COSTS & MYTHS

It's the big question that's continually asked: Is liquid-cooling worth it? At least on a custom scale? Well, that depends. You'll definitely get lower temperatures by taking advantage of that thermal heat dispensing method, but your hardware won't run any faster because of it. The one big advantage is a reduction in overall noise, thanks to the opportunity to run your fans more slowly. However, the cost is huge in contrast to more traditional cooling methods—for a really good-looking loop, you can expect to spend anywhere between $400 and $600 at a minimum. Compare that to a well-armed AIO, and it immediately becomes less attractive.

So, is it worth it? You need to consider your available budget and how much you covet silence and cooling. If the answer is "A lot," then liquid cooling is for you. If not, a good old air tower or AIO with some quiet fans may be a cheaper solution instead.

Fixing boot issues

We've all been there: the panic, the tentative push of the "On" button, the silence of zero boot. Here's a few quick solutions.

TIP 1 IT'S PROBABLY MEMORY

The number of times we've fixed a boot issue due to memory is staggering. A good way to diagnose these conundrums is via the on-board mobo debug code display. It typically displays a number (circled above), depending on the running state of your motherboard. If nothing appears on your screen, and everything's plugged in correctly, check the BIOS debug code for your first hint; 90 percent of the time, it will say it can't detect the memory. Your best bet? Reseat the memory. If that doesn't work, reseat the processor. And if that doesn't work, try moving your memory to the additional memory slots. If you're still not having any luck, it's time to work out whether your memory is DOA. To do this, you'll want to try each stick separately. And if you're still not having any luck, it's probably time to RMA those suckers.

TIP 2 RMA & RETURNS

There's a reason we suggest going with named brands: warranty. EVGA's warranties and customer service are legendary, same goes for Corsair. If you've got an issue, raise a ticket with the customer support team, and given the evidence, it will likely exchange your part for a fresh one. So, if common sense, the manual, or Google fails you, RMAing might be the way to go.

TIP 3 FRESH INSTALL WINDOWS

We've also seen our fair share of OS-related issues, especially when transferring old hard drives to new systems. It can be anything from driver conflicts (always uninstall AMD/Nvidia drivers before swapping to the competitors cards), to corrupt OS files, to program conflicts. Ultimately, we always recommend you do a completely fresh install of Windows on to your SSD—not a refresh, not a reset, but a completely fresh install.

TIP 4 CABLES, CABLES, CABLES.

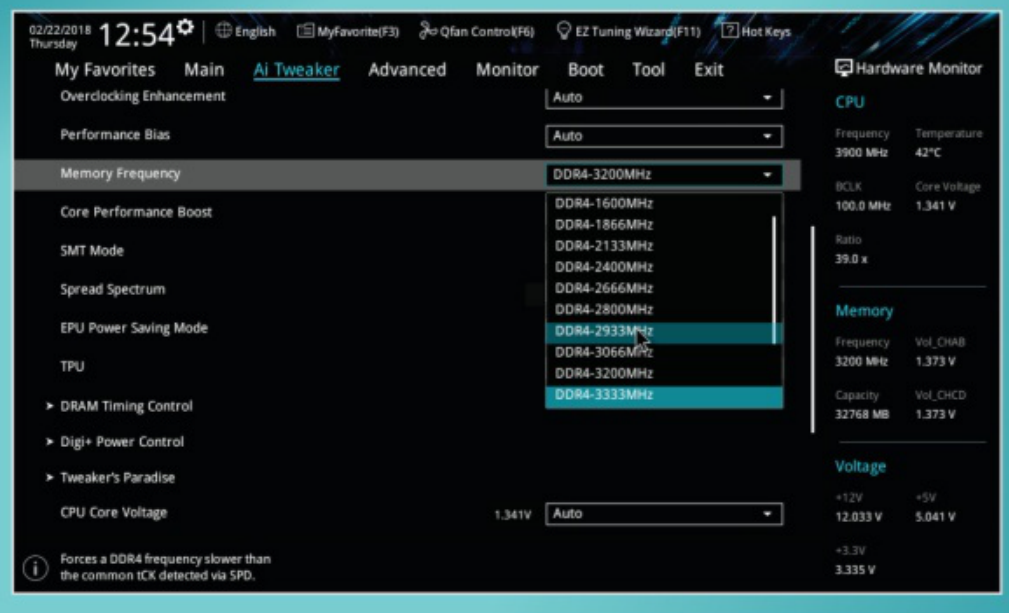
We've all done it—forgotten to plug in the PCIe power, not attached front panel connectors, had a cheap DisplayPort cable…. You can guarantee all of us here have probably built a system and missed plugging a cable in at least once. Display connection cables, in particular, are chronically bad for this—the number of crappy DisplayPort and HDMI cables we've handled over the years is horrific. In short, make sure everything's plugged in where it needs to be, and your system

AUTO OVERCLOCKS

Nothing says "problematic" quite like an auto-overclocking motherboard. We've seen it across multiple generations now, as manufacturers try to differentiate their motherboards from each other. It's pretty prolific with Coffee Lake, as Asus pumps up the default VCore in its motherboards to boost processor performance in benchmarks (in short, enabling more stable turbos at higher frequencies at stock). This is great, up until you start noticing temperature spikes of 20 degrees or more compared to the competition.

We've seen this with memory profiles, too. Early on with AMD memory, frequency support was haphazard across a swathe of motherboards, with 2,400, 2,800, and 3,000MT/s causing boot loops and more. Threadripper still can't support 128GB of DDR4 at 3,200MT/s.

So, what's the solution? BIOS tweaking. If you're having thermal issues, check that your heatsink is securely fastened to the motherboard; if it is, adjust the VCore in the overclock settings. Typically, we recommend 1.2V for most Intel Sky Lake, Kaby Lake, and Coffee Lake products. For memory frequencies, try enabling the XMP settings, and dropping the frequency by 200MHz or so to alleviate some overclock conundrums.



Installation protocol

Whether you're building a brand new rig or refreshing an old one with a clean build of Windows, you'll find our invaluable installation guide will leave your system running as smooth as silk.

TIP 1 UPDATE THE BIOS

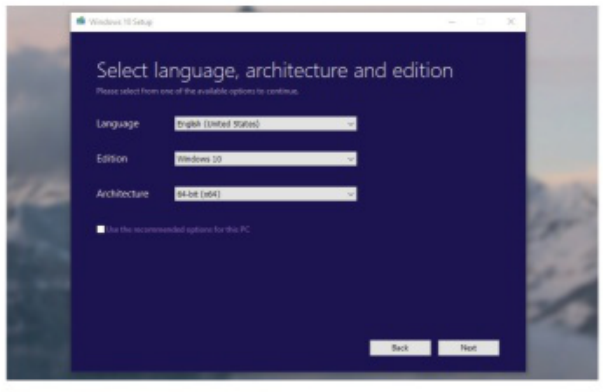
BioS updates used to be a daunting experience, leading to bricked mobos and dead CPUs. Now, it's really beneficial, and we recommend you update your BIOS whenever a new one launches. Go to your mobo manufacturer's website, find the page for your model, and head to the support section. Go to driver downloads, and search for the BIOS subsection. Download the latest version. Extract this file on to a 4GB USB stick that's been formatted to the FAT32 filesystem, then plug it into the back of your motherboard, head into the BIOS, and find the update BIOS tool in the advanced menus. Select the USB stick, find the file, and load it—your motherboard takes care of the rest.

TIP 2 FAN CURVES

While you're in the BIOS, take a look at tweaking the fan curves. If you're plugging all your fans into PWM headers, setting a quieter fan curve can reduce noise, and make your PC experience far more enjoyable. It varies from board to board, but we recommend you set a low curve (35 percent power) all the way up until you hit about 60 C, at which point, you can start ramping up those curves.

TIP 3 INSTALLING WINDOWS VIA USB

Installing a fresh copy of Windows 10 is fairly simple nowadays, especially if you've kept your digital key, or your Windows 10 license is linked to your Microsoft account. Head to **http://bit.ly/Win10MediaKit**, download the Media Creation Tool and Create Installation Media on to an 8GB USB stick. Plug the USB stick into the back of your system, go into the BIOS boot order, and boot from the USB stick. From there on out, follow the prompts. You're asked to sign into your Microsoft account during the installation process; you can do this now, or create a local account and deal with it later. Once logged in and on the desktop, you can type "Activation" into the Start menu, and either log in to your Microsoft account to verify your new install, or insert your Windows code—and you're done. If you have access to the Internet, now is a good time to install any updates.



TIP 4 INSTALLATION PROCEDURE

What's next? Chipset. Head back to your motherboard manufacturer's website, head to support and driver downloads, and download the latest chipset driver for your rig. Once you've got that, download any additional drivers or utilities you may need. For a lightweight build, all you really need is the LAN and audio drivers. Install the chipset first, then hit "Restart." Now you can install the rest. Next, grab your graphics drivers. By default, Windows installs an older driver variant through Windows Update. Head to **www.geforce.com/drivers** or **http://support.amd.com/en-us/download**, and download the latest driver for your card.

TIP 5 NINITE

Finally, it's time to install any programs you need. Ninite (**www.ninite.com**) is our go-to tool for the quick installation of essential apps. Choose what programs you want, and install directly to your C drive. Ninite only installs to C, so if you want to keep Steam on a separate drive, pass on that, and install it separately. Once done, you'll be good to go. PC

Back to the basics build guide

An in-depth step-by-step budget build guide.

For the experienced, building a PC is an easy, often therapeutic experience. Each part fits into its designated slot, each cable is carefully woven around the frame, and each power-on is successful. However, for a vast swath of folk, it's nothing of the sort. PC building can be a daunting task, especially if it's your first time. After all, you're messing around with delicate parts that can cost upward of half a month's paycheck. One little slip, one jolt of static, one cable in the wrong place, and boom—you're out of pocket and out of luck.

So, why bother? You can pick up a pre-built PC for a similar amount of cash as building your own—and let someone else worry about everything. It's convenient, easy, and saves a whole ton of time. Combine all that with numerous tech sources and journalistic outlets (ourselves included) focusing on the very extreme end of computing, and finding the info you need to take you through the process of building a system right from the start is challenging.

However, the fact is that, more than anything, building your own system is actually a relatively easy and satisfying experience. It's about taking the exact hardware you want, and combining it all into something that suits you perfectly. By building your own rig, you know exactly what goes in it, where potential problems can arise, and what you can do to improve it. On top of that, it's yours. You built that, nobody else, not another company—you.

This time around, we decided to pull out a bit of a double whammy. Firstly, we're talking a sub-$1,000 hardware budget, and an attempt to build a fairly respectable 1080p gaming machine, with all the gizmos you need, including 620GB of storage, an SSD, 8GB of DDR4, and a fairly meaty processor. Or, at least, enough to get by just fine with the latest titles. We're combining that with a super-granular, in-depth guide to take you from the very beginning to the very end of your own budget build.

ZAK STOREY

INGREDIENTS

PART		Price
Case	Cooler Master MasterBox Lite 3.1	$59
Motherboard	Gigabyte B360M HD3	$115
CPU	Intel Pentium Gold G5600	$180
Memory	8GB (2x 4GB) Crucial Ballistix Sport LT @ 2,400MT/s	$85
GPU	Gigabyte GeForce GTX 1050 2GB OC	$220
PSU	EVGA BT450 80+ Bronze	$60
OS Drive	120GB Kingston A400 2.5-inch SSD	$35
Data Drive	500GB Western Digital AV-GP 3.5-inch HDD	$59
Cooling	Stock	$0
Operating System	Windows 10 64-bit	$149
Total		**$962**

Prices were correct at time of printing

CPU

INTEL PENTIUM GOLD G5600 $180

Where would we be without the core wars between AMD and Intel? Since Intel has had to up its game and push more cores into its lineup, we're finally seeing some of the budget-oriented processors reach higher heights than we've seen in the past. The Core i3s are now akin to Kaby Lake i5s, and the Core i5s hold nearly the same multi-processing grunt as the old i7s. So, where does that put the Pentiums?

Well, this little beauty, coming in at $180, packs two full-fat cores, plus Hyper-Threading, to give us a total of four threads, all clocking in at a base frequency of 3.9GHz. That's not exactly a small figure there. Ultimately, all of those stats come together to give us a fairly fast Coffee Lake processor that's more than capable of driving the latest games with ease. It also comes with a cooler as standard, so win-win.

Motherboard

GIGABYTE B360M D3H MICROATX $115

With a good processor, you need a good mobo. We've sprung a little extra cash into this purchase, but in the long run, it's very much worth it. Gigabyte's B360M D3H is a microATX fun house of future connectivity. You've got multiple SATA ports, support for onboard USB 3.0 and 2.0, four PWM fan headers, support for all of the Coffee Lake series of processors (from our lowly Pentium all the way up to the Intel Core i7-8086K), and, more importantly for us, support for an M.2 PCIe SSD, which will be a massive boon if you do fancy chunking out for some beefier storage later down the line.

Unlike most systems out there, ours does have a fairly accessible and easy upgrade path, for those looking to get more out of their rig later down the line. It would be easy to throw in a Core i5, a beefier GPU, and a more advanced storage solution without breaking the bank. And on top of that, your mobo won't look out of place, either.

Memory

8GB (2X 4GB) CRUCIAL BALLISTIX SPORT LT @ 2,400MT/S $85

We've seen in the past that Intel-based systems don't really benefit much from advanced memory frequency speeds, outside of more intensive workloads, particularly video editing. And with the recent fall in memory prices, picking up an 8GB kit of dual-channel memory isn't quite as daunting as it once was.

8GB is plenty for all your gaming needs, especially at 1080p. It's likely that within the next four years, you may need to double that capacity, but only for the highest of high-end titles. Fortunately, the Gigabyte B360 motherboard supports four sticks of DDR4, so it would simply be a case of buying a second set of the Crucial Ballistix Sport LT featured above.

GPU

GIGABYTE GEFORCE GTX 1050 2GB OC $220

Nvidia's GeForce GTX 1050 2GB isn't going to wow your friends, but there's no arguing with how impressive it is regarding value for money. We've come a long way graphically in the last few years, with Nvidia's tenth-gen series of cards revolutionizing what you can expect across the range. To give some clarity to that, in our testing, the GTX 980 performs almost identically to a GTX 1060. The 1050 is a somewhat slower card than its bigger brother, but it still packs just enough punch to tackle most 1080p titles. Basically, you need to be smart with your settings. You can't just throw everything to Ultra and leave it there if you want an acceptable frame rate. Most mainstream esports titles, Overwatch, MMOs, MOBAs, and the like will play well into the 100fps mark, but for any other graphically intensive title, you should drop the quality of the textures and lower antialiasing where you can to reduce the overall load on the GPU.

OS drive

120GB KINGSTON A400 2.5-INCH SSD
$35

What would any modern system be without a solid, quick, and dependable hard drive behind its OS? Nothing, that's what. Sure, those old spinning platters may be far cheaper than their flash-based rivals, but nothing compares to having the instantaneous response of an SSD. It's one of the biggest leaps you can make as a PC enthusiast, swapping from a hard drive to an SSD, and we certainly wouldn't build a system nowadays without one. Whether it's 2.5-inch or M.2, there's an SSD for everyone, at any budget.

Because we're on a tight budget, we've gone for a 120GB model for our build. It's not the flashiest of drives, but it does pack impressive 500MB/s read and 450MB/s write speeds into its incredibly affordable frame.

Data drive

500GB WESTERN DIGITAL AV-GP 3.5-INCH HDD
$69

It's scary just how little you can pick one of these beasts up for nowadays. OK, 500GB isn't exactly an average-sized hard drive—ideally, you want something around double that size—but if you're on a budget, and don't mind being a little more scrupulous with your games and content, in this age of digital streaming at least, running with a 500GB HDD for your backup drive isn't exactly too much of a stretch.

Western Digital is one of the better hard drive brands out there. And although the AV-GP isn't one of its mainstream drive ranges, we've no doubt this $69 box of joy will serve you well. There is one caveat here: It does only support SATA 3.0 Gb/s, but that's still the equivalent of sequential read and writes nearing 375MB/s, and you won't find any spinning platters capable of driving those kinda numbers without paying a lot more.

PSU

450W EVGA BT450 80+ BRONZE ATX $60

We've stressed plenty of times in the past just how important buying a decent PSU is, and we'll stress it again: Regardless of price, always go with a named brand, because if things go boom, you want a company you can talk to, not some Amazon non-branded reseller. EVGA's BT450 is by far our favorite budget power supply. It packs plenty of juice for any modern-day system (twice as much as what is needed here under load), and also comes with an impressive three-year warranty. Of course, it's not the most efficient of power supplies, it's non-modular, and that warranty isn't as good as the 10-year titans EVGA also sells, but for the price, it's arguably one of the best choices you can make.

Case

COOLER MASTER MASTERBOX LITE 3.1 MICROATX $59

Where would we be without a case? To be fair, if you were on a ridiculously tight budget, you could forsake the case and run the rig off the motherboard box (something we do for testing), but long-term, you'll want to get yourself something solid.

Cooler Master's MasterBox has been a solid favorite of ours for a while, and this microATX offering is no different. Although stripped down in comparison to some of the other MasterBoxes, the 3.1 still keeps some of the basic design elements, alongside a few nifty cost-cutting measures. Take the windowed side panel—it may look like tempered glass, but it's actually acrylic. There's not a huge amount of room for cable management, but the size of the rear side panel has been increased to compensate for your cable bulge. It still features a full-fledged front I/O, and, rather incredibly, white and black accents if you want to change out the red ones on the front panel.

The Budget-Busting 1080p Build

With just $1000 is it possible to build a PC capable of gaming on today's 1080p planet? Let's find out...

Back to basics—how on earth did we come up with this one? Well, as graphics card prices have fallen, and the cost of memory is more reasonable than it has been of late, we thought it was time to see what you could do with an absolutely minimal budget. You'll notice we keep referring to a "hardware budget" in particular—that's because the operating system cost is one of the biggest variables.

In reality, this system is designed with Windows 10 in mind. You could game on Linux for free (or by paying a donation of your choosing), and we've covered that before—unfortunately, though, for now, Microsoft very much holds the keys to the kingdom. If you have a license already, it makes this build ridiculously affordable. Those not so lucky have two options: Either you can chunk out for a full license, bound to an email address, which will set you back around $100 or so; or you can see whether you can buy yourself an OEM one-time Windows 10 code online. These are typically available from less reputable sellers, and usually, if you can purchase a legitimate key, you'll find that it's a one-hit wonder. Pop that motherboard out, and whammo—you'll need a new key. We always recommend you pick up a legitimate Windows license from Microsoft, and anchor it to an email account. If you do, activating any new machine is a piece of pie. Simply log in with your Microsoft account, and you're good to go.

PRICE VERSUS PERFORMANCE

So, where do you begin with a build like this? Well, for us it all started with the processor. Knowing Coffee Lake to be the beast it is— and in a lot of ways, we have AMD to thank for this—means that we know those single cores can hammer out some seriously strong IPC. What that translates to is plentiful frame rates in game, and a smooth desktop outside of it. Thanks to the Coffee Lake core count bump, the Pentiums of today easily match the Core i3s of 2016 and earlier. In the process, they've become an ideal part for some low-end gaming.

Now, you could technically do something similar with an AMD build, but you'd be laying down a lot more cash in the process. Yep, we never thought we'd say this, but Intel's budget offerings are actually pretty incredible right now, and AMD currently can't match them on price.

Next on the list was the notion that prior to working for this mag, this journo was only using a GTX 660 2GB to game on back in 2015. All in all, it was a pretty comfortable experience, especially at 1080p. Games have come a fair way since then, but the reality is that game developers always cater to the largest portion of the community, meaning they need their title to look awesome on the high-end settings, but be accessible at the mid-range, too. The GTX 1050 2GB is the perfect fit, then. It's the successor to the GTX 950, which, in turn, supplanted the GTX 760 and the GTX 670. So it must, by default, be a capable gaming GPU.

Combine that with 8GB of DDR4 and a decent-sized SSD for your OS install, and you're suddenly looking at a very appealing platform for anyone who's looking at getting into PC gaming or building their kid a system, or simply someone who wants a good all-round machine.

INGREDIENTS

PART		Price
Case	Cooler Master MasterBox Lite 3.1	$59
Motherboard	Gigabyte B360M D3H	$115
CPU	Intel Pentium Gold G5600	$180
Memory	8GB (2x 4GB) Crucial Ballistix Sport LT @ 2,400MT/s	$85
GPU	Gigabyte GeForce GTX 1050 2GB OC	$220
PSU	EVGA BT450 80+ Bronze	$60
OS Drive	120GB Kingston A400 2.5-inch SSD	$35
Data Drive	500GB Western Digital AV-GP 3.5-inch HDD	$59
Cooling	Stock	$0
Operating System	Windows 10 64-bit	$149
Total		$962

Prices were correct at time of printing.

1

PRE-BUILD PREP

So, the hardware's turned up, you've got a solid work area to build your rig in, and you're good to go. What's first? Well, after taking your woolly socks off and touching something metal to get that zappy goodness out of your fingertips, you're going to want to unbox your chassis. This is where you'll encounter a few issues. Firstly, with polystyrene and a plastic bag sliding out of a cardboard box it means that every case will almost always zap you with static electricity. So, de-charge yourself again immediately after you remove the case, polystyrene, and plastic bag from the box. Then place both the polystyrene packaging and bag back in the box for later.

2

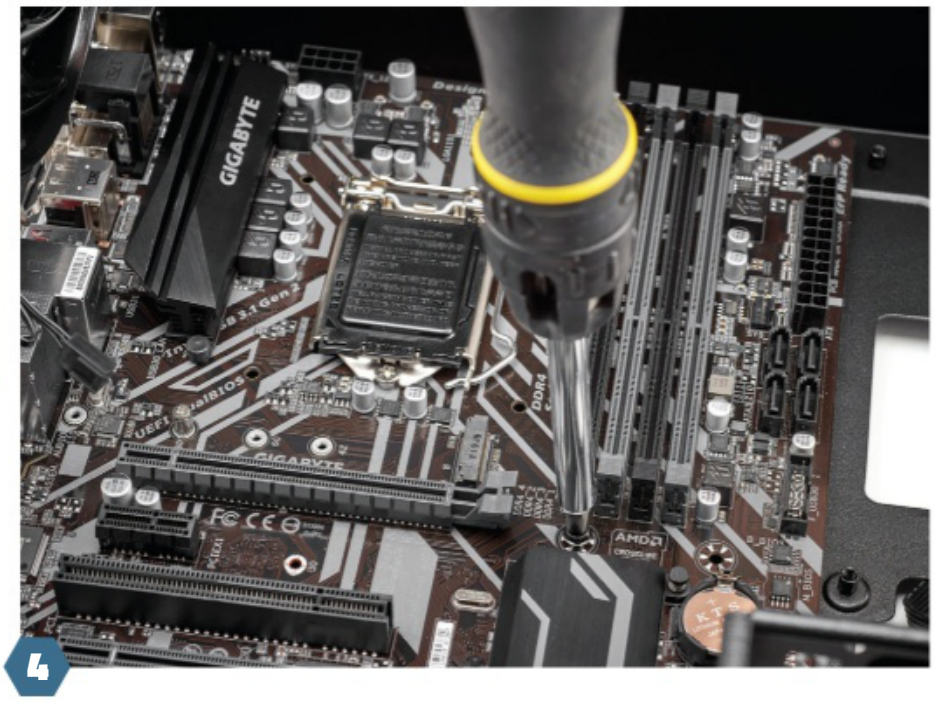
CHASSIS STRIPDOWN

Next you'll want to empty out the chassis as best you can. There's almost always some form of accessory bag included, with the relevant screws, cable ties, and other helpful things (in this case, a box with the black and white accents). Remove as many panels as you can, either by removing the thumbscrews, or by popping the plastic pegs out. Then place the panels back into the cardboard box for later. It's also worth getting a bowl of some description, in which to place the screws you'll be using, because it stops them from rolling around all over the place. Some of the thumbscrews can be overtightened from the factory, so it might be helpful to use a screwdriver to give you a little extra leverage on the tricky ones. Also, leave the front I/O cables tucked somewhere inside the case for later.

3

MOTHERBOARD I/O

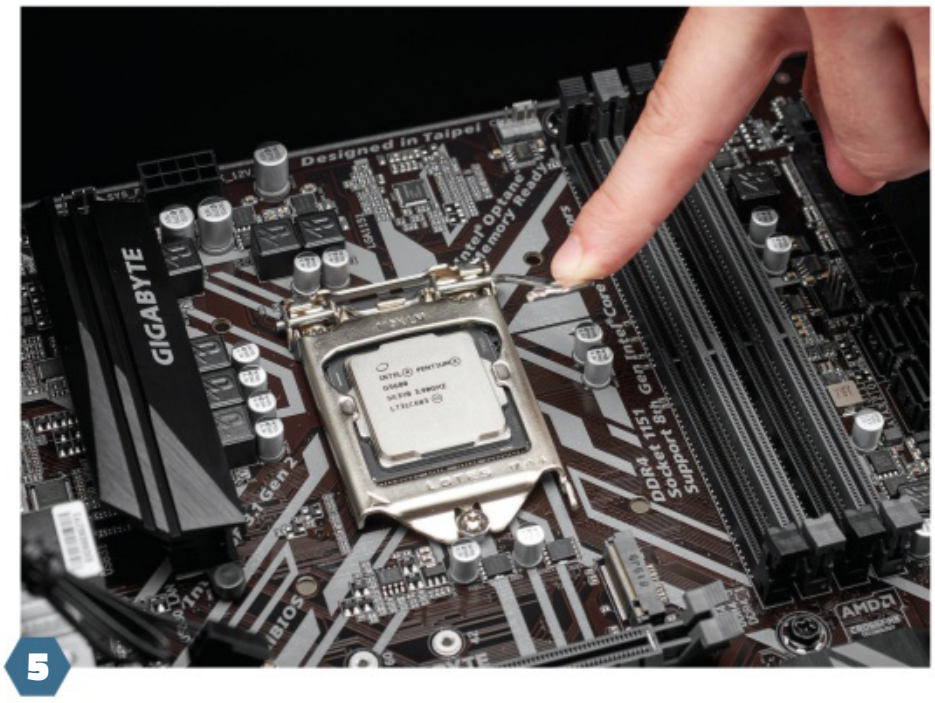
The number of times we've forgotten this little plate. Now you've got everything out the way, you can install the backbone of your system: the motherboard. First, open the box and find the rear I/O plate, located below the board with the accessories. It's a rectangle that goes in the back of the case to protect your I/O from damage. Look at your motherboard, see which side the holes need to be for each portion of I/O (audio is almost always closest to the GPU slots), then push the I/O bracket into place, from the inside of the chassis. It should click into place quite easily. Some of the more padded brackets can take a bit of extra force to get to sit correctly, and some premium mobos have I/O shields pre-attached, so you don't have to worry about those.



4

STAND-OFFS & SCREWS

Depending on your chassis, you might need to install the stand-offs yourself. These are tiny screws with a thread on the top that give your motherboard a raised platform to stand on. In our case, Cooler Master includes these inside the screw bag, with a neat Phillips head stand-off screw installer. Look at the chassis, and note the "M" on the pre-drilled threads in the case. This is where you need to install the stand-offs for your microATX motherboard. Check where the stand-offs are going against the screw holes on your motherboard. You may find some aren't on the motherboard, or the motherboard doesn't cover all the stand-offs—this is fine. Once you've got the stand-offs in, place the motherboard on top of them, wedge it up against the rear I/O plate, and screw it into place.



5

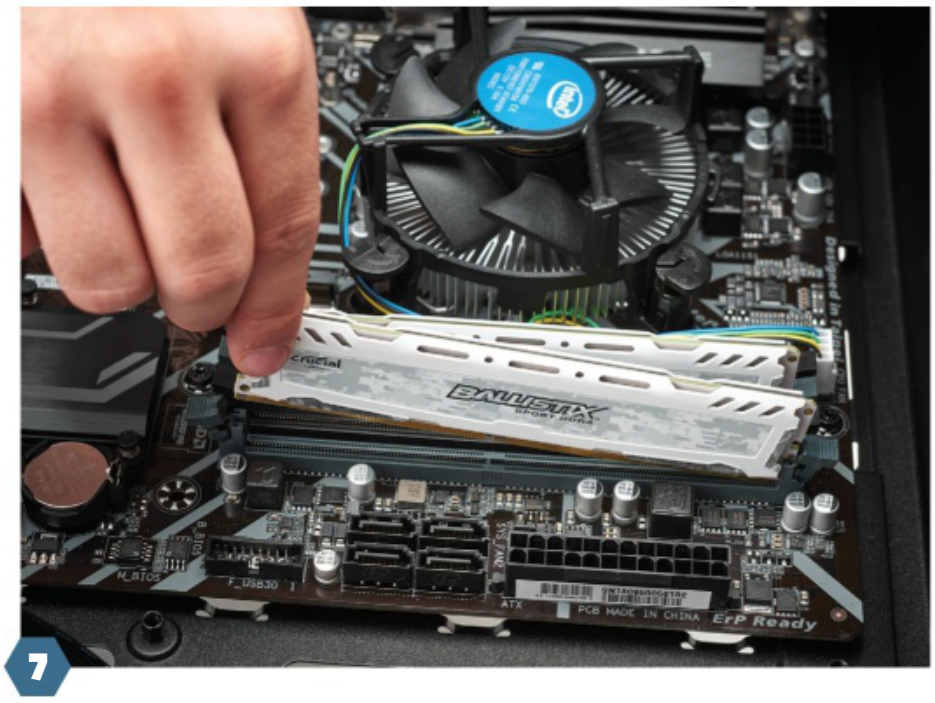
PROCESSOR INSTALLATION

Now your motherboard is securely in place, it's time to install the big bad. And by that, we mean the processor. It's a scary business installing Intel processors, not least because if you bend one of those pins in the socket, it'll mean a quick RMA, and a halt on your build. For an Intel system, you're going to want to note the location of the triangle etched in the bottom-left corner of the silver CPU bracket. Push down and lift up the retention arm you can see us holding here. Then, noting the golden triangle on the corner of your CPU, gently place it into the socket. No wiggling, no forcing, just so the triangles are in alignment, and everything fits comfortably. You can leave the black plastic cover in place. Carefully secure the bracket back down under the screw, then push the retention arm back down and under to secure the CPU. The black plastic cover will pop off. If it doesn't, gently pull it.

6

THERMAL COOLING

Processors get hot, which means you need to cool them. We're using the stock fan Intel provides with its non-unlocked processors. It's more than enough to keep our build happy. Usually, we'd apply a small dot (half a pea size) of thermal paste in the middle of the processor before attaching a cooler of some description. However, in this build, the stock Intel cooler has thermal paste pre-applied to the bottom. Simply remove the plastic cover on the heatsink, line up the four pegs on each corner of the fan with the holes in the motherboard surrounding the CPU socket, and push them into place. Once there, rotate the pegs counterclockwise to lock it in place. Then run the CPU fan cable to a PWM fan header on the motherboard. These look like four pins, and are usually labeled. We recommend you install this into the CPU one. There's a notch on the cable to stop you plugging it in the wrong way, and you may need to remove the cable from the clips holding it on to the CPU fan to reach around the other way, as we have here.



7

MEMORY MATTERS

Now you've got your CPU fan installed and plugged in, it's time to install the memory. You should have bought a dual-channel kit for your build. To install this, notice the notch on the bottom of each stick, where the connectors are. You need to line these up with the notches in the memory slots. Lift up the latches on both sides of each memory slot, then lining up the memory stick, carefully slot it into place, until both latches on either side click down securely. Additionally, unless you're installing four sticks, make sure you use the color co-ordinated memory slots, to enable dual-channel memory speeds. Under no circumstances should you be using a single slot of memory for your build, because this limits overall memory bandwidth by half, regardless of how much memory it gives you.

8

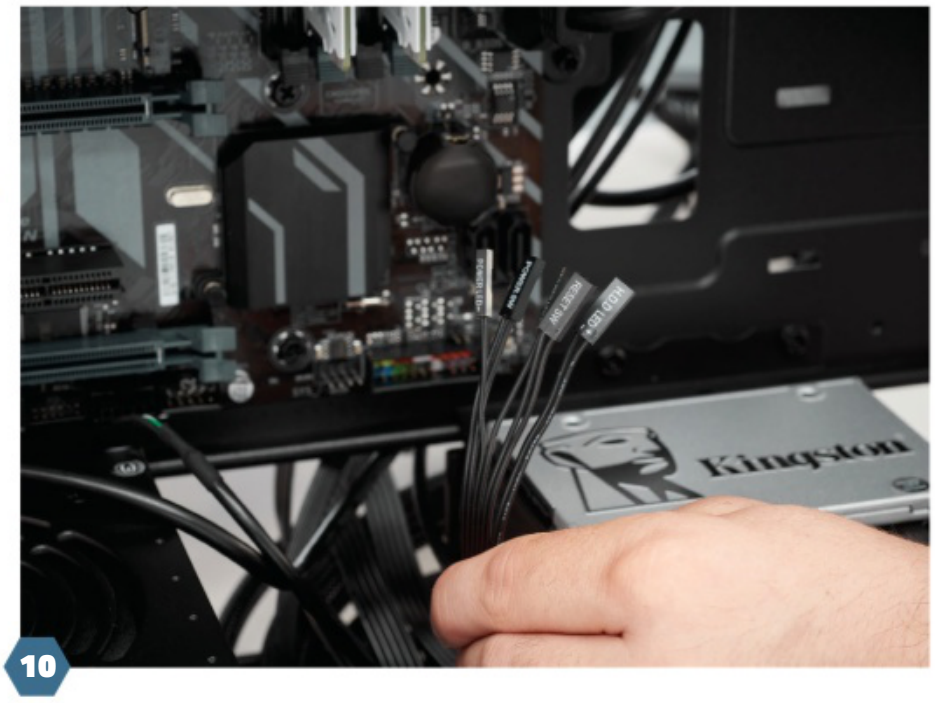
HARD DRIVES FOR DAYS

In our build, we have both a 2.5-inch SSD and a 3.5-inch HDD. The SSD is for our operating system, because it has limited storage, but is incredibly fast, and the 500GB HDD is for everything else. To install the 3.5-inch hard drive, slide it into the caddy, as pictured here, with the ports facing out toward the back of the case. Then, simply use one of the included thumbscrews to secure it in place. The SSD slots into the top, and is secured by two small screws at the front. We decided to angle the ports, so they were facing the motherboard, to make it a little easier to run the cables later. You can also install the SATA data transfer cables now. You'll find these in your motherboard box; they have L-shaped connectors. Connect one to each hard drive, then run it through the back of the case, and into one of the L-shaped ports on the motherboard.

9

POWER SUPPLY INSTALLATION

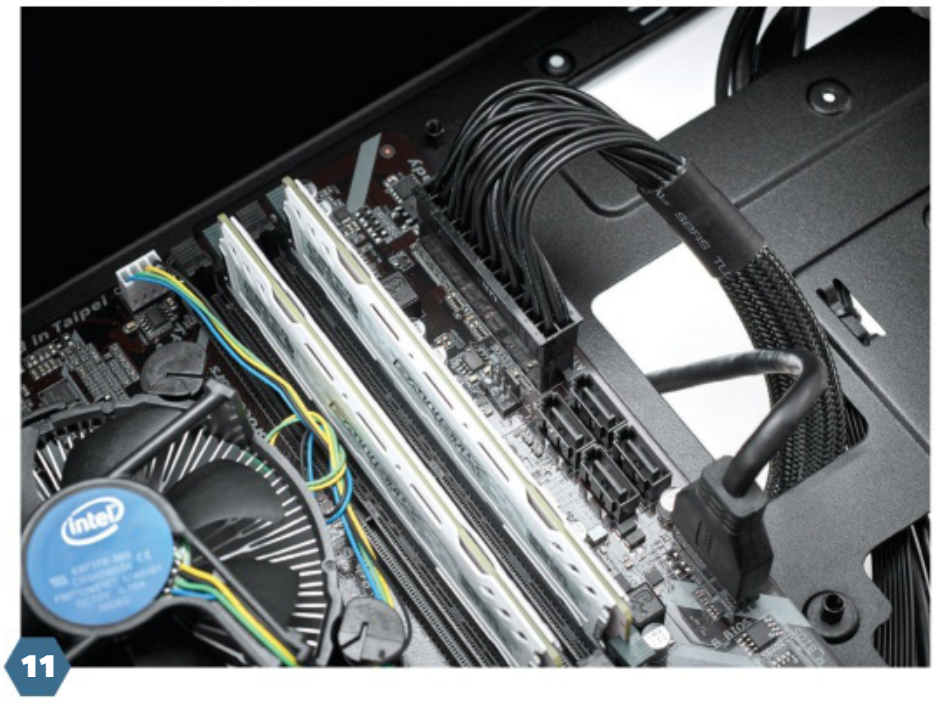
When it comes to installing the power supply, you have two choices: fan down, or fan up. In a liquid-cooled build or one with an AIO, we recommend you install it with the fan facing down. If any water leaks from the cooling block, there's minimal chance that gravity will drag it into the fan and fry the system. With the fan up, it draws warm air down and out of the chassis. It also affects how much play you have in the cables when you're installing them. Once the PSU is in place, simply use thumbscrews to secure three or four of the threads through the back of the chassis, then run the cables out through the back of the case, next to the motherboard.



10

FRONT PANEL FUN

So, you've got the PSU installed, and all the cables out of the back, so now it's time to plug in all the front panel connectors. Usually on the bottom-right of the motherboard, you'll find a selection of pin-outs to which you can attach the connectors. Your motherboard manual will tell you which connector needs to go where, but usually on the mid-range options and above, those details are actually written on the motherboard itself as well. With the MasterBox, the front panel connectors come bunched up on a group of wires, all attached together—you can pull these apart and separate them slightly to give you some leverage to plug them into the correct position. It's also a good time to plug the audio pass-through (located bottom-left), the USB 2.0 header (check the pin slots on each plug, so you don't get confused with the audio pass-through), and the USB 3.0 header into the motherboard.



11

ATX POWER INSTALLATION

Now the PSU is in, the front panel cables are all connected, and your USBs are firing, it's time to add some power to your system's main hardware. First up on the list is the 24-pin ATX power. You'll recognize this cable simply by its sheer size. Most power supplies come with a 24-pin that splits up into two segments: a 20-pin and a 4-pin. This is to support older motherboards that don't require the full 24-pin power. However, our system very much does. Simply clip the additional 4-pin power into place on to the side of the 20-pin cable, note the latch on the cable, line it up with the notch on the motherboard, and push it into place. Job done—first cable all sorted.

12

CPU POWER INSTALLATION

Your mobo's got juice, so let's sort out the CPU. Your EPS power cable looks like a PCIe power cable, although it usually has EPS or CPU written on the plug. Its pins are also different shapes, so there's no way you can plug a PCIe power connector into a CPU connector. On a bigger chassis with better cable management, you'd run it up the back of the motherboard and into the eight-pin socket. In our case, there are no cut-outs to do that. There's also not enough cable to run it from the side. We could run it straight up from the power supply, but that's messy. Instead, we'll unscrew some of the screws holding the mobo in place, near the socket, then thread the CPU power through the CPU socket cut-out on the mobo tray, then up into the power supply slot, letting the mobo stand-offs act as cable management space, before securing the mobo back down.

13

GRAPHICS CARD TIME

Now you're all powered up, it's time to fit your GPU. To do this, you'll first want to remove two of the PCIe covers located at the back of your rig. Find the two that are closest to the topmost PCIe slot. Use a screwdriver to remove them, and set them to one side. Then, take your GPU and carefully slot it into place, with the rear I/O pointing out toward the back of the case, from where you removed those PCIe covers earlier. Once that's done, push it into place until it clicks into the slot. Finally, secure it down with the two screws you removed from the PCIe bracket covers earlier, and that's all there is to it.

14

GPU POWER

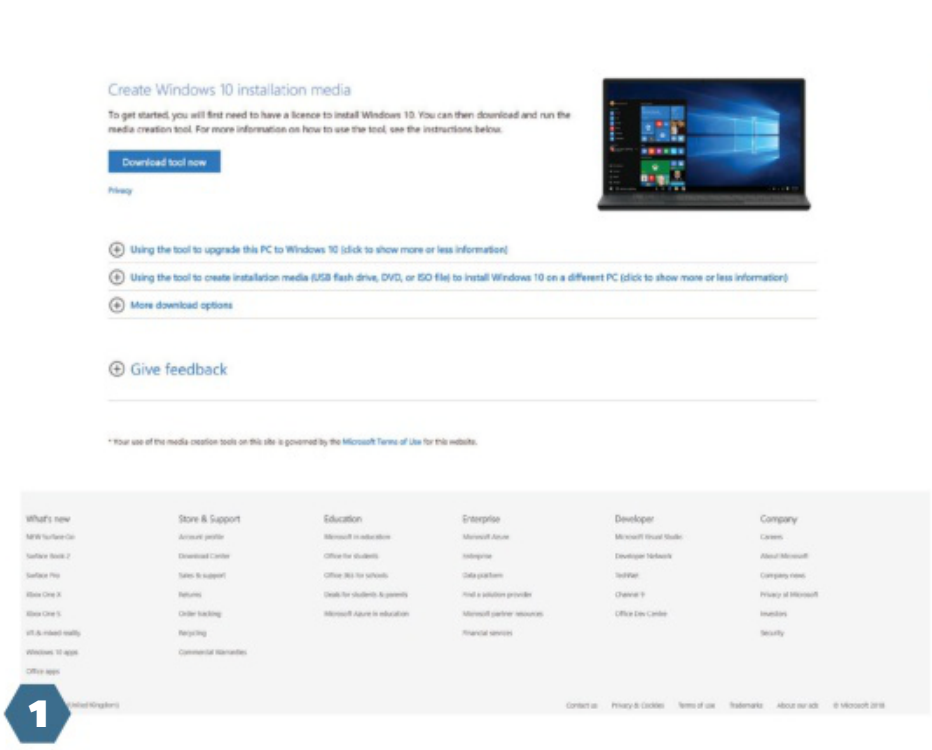
Some graphics cards need additional power, because although they draw power directly from the PCIe slot they're placed into, the higher-end cards demand more juice to run correctly. Don't worry if you forget, and you power on the system without it, because you'll receive a message on boot telling you to power down the machine and plug in the additional cables. PCIe power cables are usually labeled, and come as a daisy-chained plug. In our build, however, our card doesn't need any additional power. So, for us, it's simply a matter of tying the cables up, and putting them somewhere out of the way in the bottom of the chassis. Once this is done, you simply reattach all the panels you removed in step one, which are safely stored in your chassis box, and you're good to go.

Set Up Your Software

From BIOS to boot, follow our guide to installing your operating system, device drivers, and a selection of essential apps, one simple step at a time.

You've made it. You've got a brand new rig, and you're ready to kick some serious ass in those 1080p games. But how do you get there? How do you install an operating system on your new machine? You haven't installed an optical disc drive in your chassis, and you don't seem to have one laying around either, so where do you go from here? No need to worry—we've got your back. The last time we used one of those DVD readers was way back in 2016, and even then that was only to see whether the coverdisc of our friends over on the Linux titles would read properly. Spoiler: It did, then they trashed our DVD drive. Typical, right?

But enough waffle. You're here to install your OS of choice. For us, that's Windows 10. You could game on Linux, if you want, but because this is PC PowerPlay, not PC Game Releases Two Years Later, unfortunately (or fortunately, depending on your point of view), we're stuck with Microsoft.



1

BOOTABLE MEDIA STICK

First thing you need to do is grab an 8GB USB stick, preferably 3.0, if you've got one. But, as this is mostly a one-time deal, it doesn't hugely matter. Then, on another system, with Windows already installed, you need to go to **http://bit.ly/Win10MediaKit** and hit the "Download tool now" button. This gives you an EXE file that you can then use to download and create a bootable USB stick. On MacOS or any Linux distro, you're given an ISO instead of this, so you have to use a third-party program, such as Etcher, to mount the ISO on the USB stick.

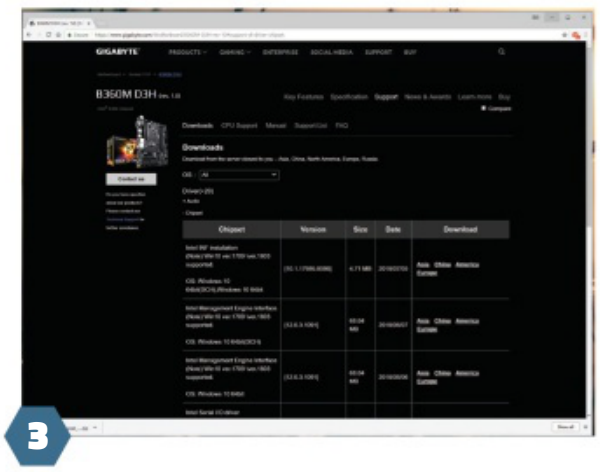
2

FIRST-TIME BOOT & BIOS

Now you've got a bootable OS USB stick, you need to plug it into your new machine, add a keyboard and mouse, connect a screen to the GPU's rear I/O, and power the machine on. Hammer the Delete key as soon as you hit the power button, and keep hitting it until you enter the BIOS.

To install Windows, we need to tell the BIOS to boot from the USB stick. Although the location of the boot order varies from mobo to mobo, the procedure is very much the same. In our build, head to the BIOS menu on the top, go down to "Boot Option Priorities," click "Boot Option #1," and select the disk that's labeled "UEFI: Your USB Drive, Partition 1." Hit F10, and select "Save Configuration and Exit." The machine reboots into the USB stick.

You enter Windows Setup at this point. Choose your language, time, and keyboard layout, then hit "Next." Windows then asks for a Windows Activation key—you can either enter this here, or do it later by hitting the "I don't have a product key" button at the bottom. Next, you need to choose the version of Windows you want to install; for us, that's "Windows 10 Home x64." Accept the license agreement and hit "Next." Then, when prompted, hit "Custom Install," and choose your SSD as your primary drive. There are no names here, but each disk does specify its total size, enabling you to select the appropriate drive. Hit "Next." If it throws up an error, or there's a partition already there, delete the partition, and try again. Windows now installs. Once the system restarts, quickly pull out the USB stick, and let Windows finish the install. Now you can select the privacy options right for you, and either log in using your Microsoft profile, or create a localized account.

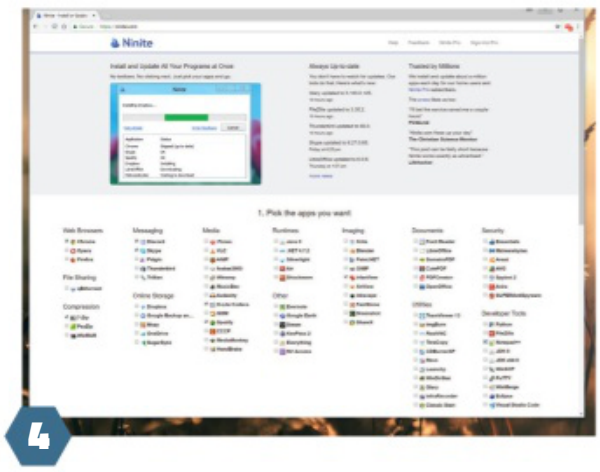


3

OF DESKTOPS & CHIPSETS

You've made it to the desktop, so what's next? That depends on a few factors. Some motherboards support Ethernet connections automatically, while others require a driver to be installed before even connecting to any network. In our case, it's the latter. So, again on another system (or even on your Android phone, if you're in a pinch), head to your motherboard model's web page (Google your motherboard model—"Gigabyte B360M D3H," in our case—and choose the manufacturer's URL). Then click the "Support" or "Download" tabs, find the "LAN" subsection, and download the relevant driver. Finally, install that on your desktop, and it gives you access to the Internet.

Once this is done, you're going to want to install the remaining drivers. First up is the chipset. From the same website, download the latest version of the chipset, along with any other software, and install it directly on your new system. We recommend that you install the chipset first where possible, before anything else, such as RGB or utility applications provided by the manufacturer, to stop any incompatibilities from occurring.



4

INSTALL YOUR APPS

Now you'll want some regular apps on your rig. A quick starting point is that long-time industry favorite, Ninite. Head to **https://ninite.com** and pick the apps you'd like to install. There's a few we recommend off the bat: Chrome, LibreOffice, Notepad++, and 7Zip. You can also install things such as Skype and Steam if need be, but if, like us, you're a stickler for having all your Steam in a single location, it's arguably better to hold off on that one until later.

If you watch a lot of media, K-Lite Codecs is a good choice. It installs Media Player Classic, which can decode and play MKV video files, among other things. You also need GPU drivers. In our case, Google "Nvidia GeForce Drivers," and click the topmost link. In "Manual Driver Search," select your GPU and OS, hit "Start Search," then download and install the driver. You can opt out of installing GeForce Experience, but then you'll need to do this every few months; GeForce Experience auto-downloads driver updates, but you need to make an account, and give Nvidia some juicy advertising details (yeah, we're not fans).

5

UPDATE THE BIOS

Now it's time to update your BIOS, and get everything ticking along smoothly. Depending on how long your motherboard has been sitting in a warehouse, you might not have the latest BIOS installed. BIOS updates typically improve stability, weed out bugs, such as Spectre and Meltdown, and can, in some cases, improve performance. Head back to your mobo's web page, and into "Support." Download the most recent BIOS update, and place it on your desktop. For a BIOS to read an update off storage, the BIOS update file needs to be placed on a memory stick or storage device that has been formatted to the FAT32 file system. Fortunately, your Windows 10 install stick we used earlier already has been.

Plug your Windows install stick into your system, create a new folder inside it called something like "BIOS Updates," take the BIOS update you downloaded, and extract it into this folder. Restart your machine and mash the Delete key to get back into the BIOS. This next step varies, depending on the motherboard (check your mobo manual). In our case, move the mouse to the bottom-right, and a pop-up menu appears. Select "Q Flash," then "Update BIOS," after which you need to find the BIOS folder you made earlier on your memory stick. Select the BIOS file in that folder, and hit the arrow to the right. Your system now starts updating the BIOS. It's imperative at this point that you do not reset or switch off your machine, or you could brick the entire board. Let it do what it has to; it may restart a few times. Once done, head back into the BIOS (we still have work to do).

6

PERFORMANCE TWEAKS

There are just a few performance options left to tweak in the BIOS. One of these steps can be ignored, but if you are a perfectionist, getting these last two things done will set your mind at ease, and ensure everything is running as it should be. Head back into the BIOS by smashing the Delete key on restart/startup. First, we'll enable the XMP (Extreme Memory Profile) settings, a pre-set list of specifications that your memory can and will run at, that are typically higher than the JEDEC standard. This means you can transfer more data to and from your memory faster for better performance in memory-intensive applications, such as archiving/zipping, and any photography or editing work you may do. For our Gigabyte board, enter the "Advanced Frequency Settings" option in the main menu, then go down to the "Extreme Memory Profile" menu, press Enter, and choose "Profile 1." This enables the correct timings and frequency for your memory.

You might also want to take a look at fan curves while you're here. You can control these with in-desktop apps, but we always find that BIOS configuration works best, and works from startup. For our motherboard, those settings are found at the bottom of the main BIOS menu. Have a tinker, and find a setup that works for you. That's all there is to it. Then hit F10, save, and exit, and there you have it—one fully working, ready-to-go system.

1

Hiding any excess cables under the hard drive caddy here is ideal for keeping things tidy, as long as you don't have more than one 3.5-inch drive, of course.

2

There are no intake fans with this build—adding two 120mms in the front of the rig would keep temperatures down, especially during the hot summer months.

3

If you're going to upgrade your processor at a later date, remember to get a beefier cooler; this slimline stock one won't cut it.

4

We love a GPU that draws power solely from the PCIe bus, although admittedly, it won't be as fast as some of its higher-spec buddies.

A GRAND OF GAMING GOODNESS

There you have it: your very own budget 1080p gaming machine. It's versatile, compact, easy to build, and looks darn good, given the limited funds we had. We could have whacked in an Intel Core i3 quad-core part or a GTX 1060 to bolster performance—two very smart moves—but that would mean a bigger budget, and not everyone has that kind of cash lying about.

We managed to stick to our $1000 hardware budget fairly well. Pat on the back for us!

But enough of that—was this build a success? Yes. It was never going to compete with our zero-point—that's a $1,100 machine packing a six-core processor, 16GB of DDR4, a PCIe SSD, and an Nvidia GTX 1060, after all—but for the price, it actually held its ratings fairly well, and despite the lackluster computational performance, the effect on real-world feel and use is slim to minimal.

In game, it's rather different, of course, with most of our tests being almost unplayable in certain circumstances, but this is where we need to get a little granular and explain the whole purpose of our build. With a system like this, you need to be a tweaker. Not necessarily of hardware or overclocking, but of graphical settings. From past experience, we know that when gaming, there are two effects that take up the majority of your processing power: antialiasing and shadows. Now, in our scenario, you'd be gaming on a 1080p 24-inch panel, so turning off AA in its entirety is a bad idea; reducing it, however, is less so. But let's give you some metrics here.

BENCHMARKS

	Zero-point	
Cinebench R15 Multi (Index)	1,152	412 (-64%)
CrystalDisk QD32 Sequential Read (MB/s)	3,400	494 (-85%)
CrystalDisk QD32 Sequential Write (MB/s)	1,720	476 (-72%)
Rise of the Tomb Raider (fps)	60	35 (-42%)
Total War: Warhammer II (fps)	46	27 (-41%)
Tom Clancy's Ghost Recon: Wildlands (Avg fps)	39	5 (-87%)
3DMark: Fire Strike (Index)	11,101	5,880 (-47%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an AMD Ryzen 5 1600, 16GB of Crucial Ballistix Sport LT @ 2666, an EVGA GeForce GTX 1060 3GB, and a 250GB Samsung 960 Evo M.2 PCIe SSD. All tests were performed at 1080p at the highest graphical profile.

In our Ultra preset benchmark test for Warhammer II, we managed 27fps. With a few minor tweaks, shadows reduced to minimal, a slight decrease from Ultra to Medium in various textures, and a reduction in foliage/tree quality, we managed 38fps, with minimal impact on overall texture quality. Take that same logic across to Rise of the Tomb Raider, and we managed 52fps. Amazingly, there's a setting that renders each individual strand of hair on Lara's head; although it looks breathtaking, during the middle of a game, it's not something we particularly notice.

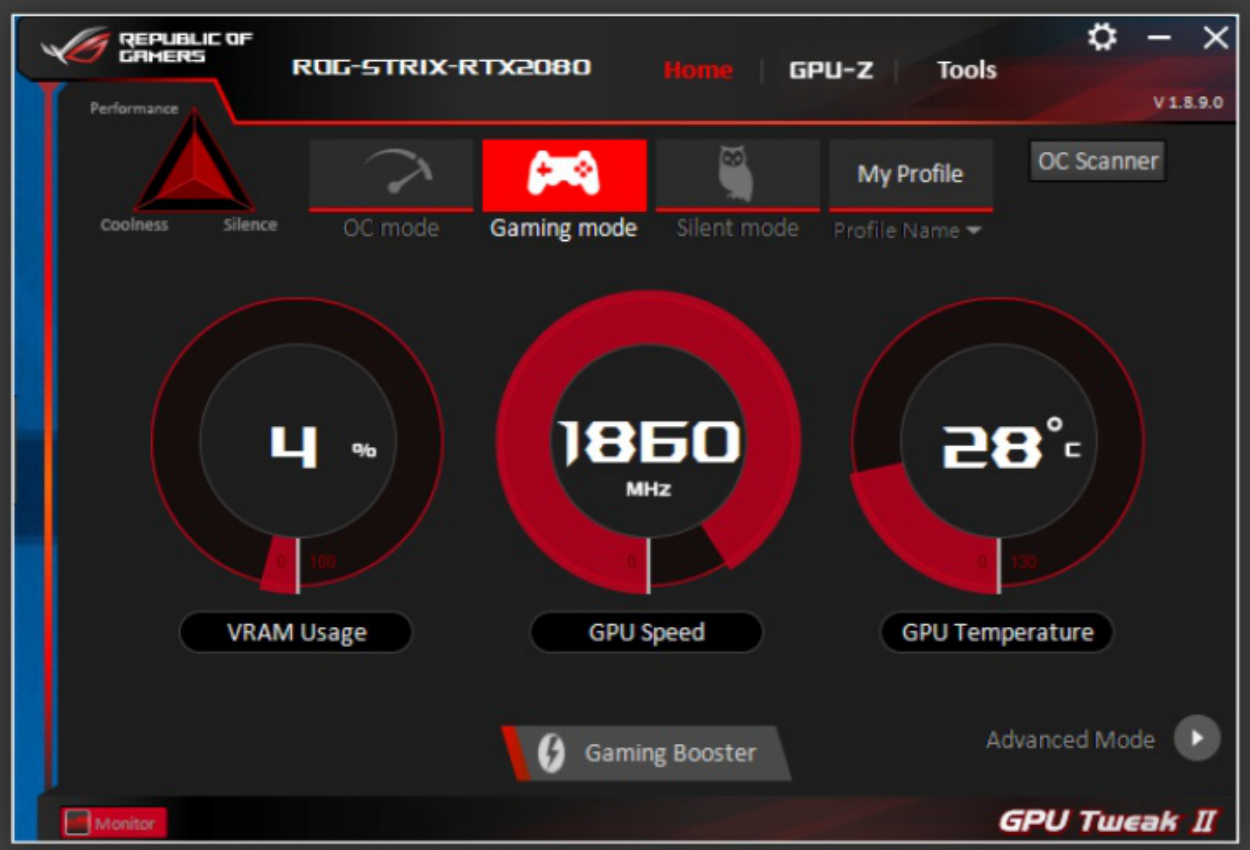
Perhaps the biggest difference was in Ghost Recon. A demanding game at the best of times, dropping the graphical profile down from Ultra to High, and again adjusting the shadow quality (not disabling it entirely), bumped up frame rates from 5 all the way up to 40fps. That's a 700 percent increase just by tweaking a profile. OK, it's a bit more messing about before playing, but even at the high end, with GTX 1080 Tis and Titans, you still go through the same process anyway, so what's so different down here at the $1000 budget? PC

ASUS: GETTING THE MOST OUT OF YOUR GPU, MOTHERBOARD, AND ROUTER

Asus has an array of smart software to help you get the most out of your hardware...

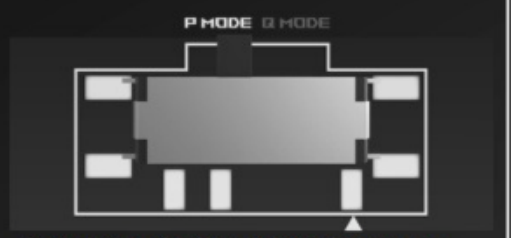
Asus is a world leader when it comes to PC parts, designing some of the best, most powerful components in the business. Whether you're looking to put together a new PC, upgrade an existing one, or even invest in a new mouse and keyboard, Asus' unbeatable range is well worth investigating. But once you've got that perfect machine, if you're a true PC fan - someone who gets a thrill out of putting their machine together with the perfect components — or a hardcore gamer, you'll want to know the best ways to test the limits of what their new beast can do.

Asus knows how important it is to real enthusiasts that they can tweak settings, overclock performance, and customise their experiences. Here are some tricks and tips for how to get the absolute most out of your Asus GPU and motherboard if you want the best gaming set up imaginable, as well as the best features of Asus' router range.

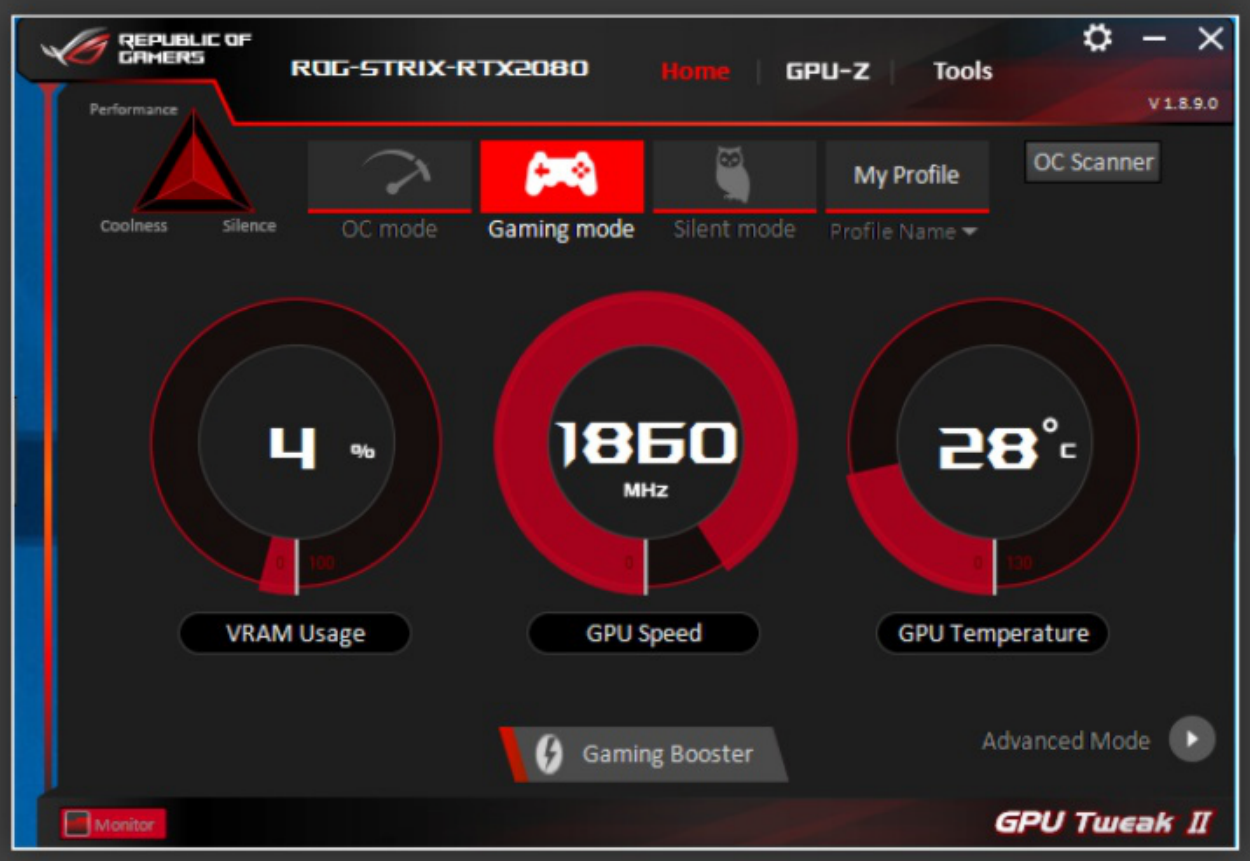


Fan	Performance Mode	Quiet Mode
Temperature	Very Low	Low
Acoustics	Low	Very Low
0dB Tech	Always Spinning	Fans Stop under 55°c

To activate performance mode, please engage Performance (P) bios mode by using the onboard switch.

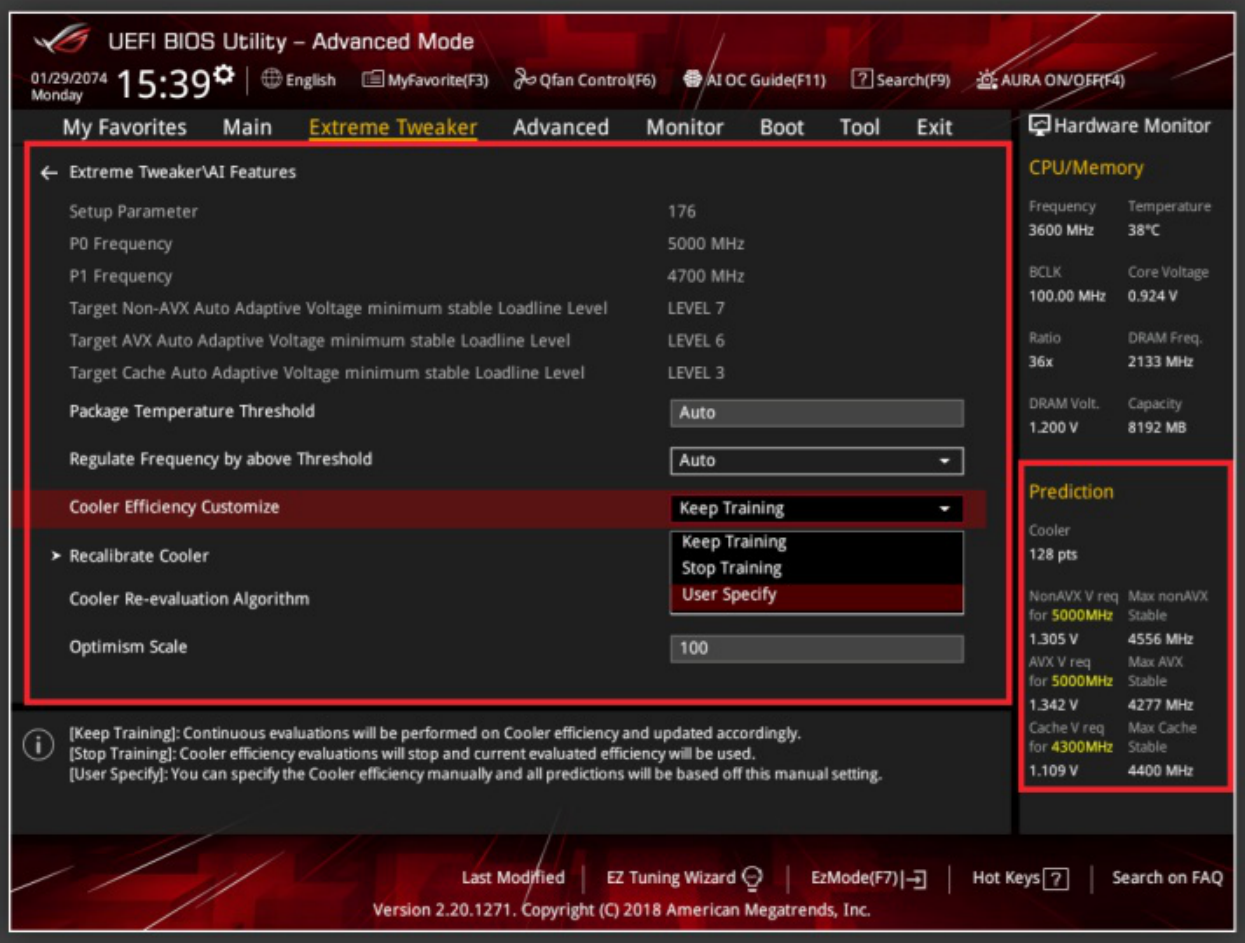


The actual location of dual bios switch on each SKU may vary. Illustration for reference only



GPUS

Asus has a huge range of GPUs available. The ROG Strix Radeon RX 580 TOP edition 8GB GDDR5, for example, offers amazing performance in high-end games with uncapped framerates, while also remaining quiet and heating up 30% less than the competition. In the Nvidia series, the ROG Strix GeForce RTX™ 2080 OC Edition 8GB GDDR6 is built with 4K gaming and VR in mind, delivering performance six times above what the previous generation of graphics card could. One of the best unique features of ASUS' range of graphics cards is their build-in performance profiles, which are easily switchable via GPUTweak II, letting you make changes on the fly depending on your usage. You can switch between OC mode (for overclocking), gaming mode, or silent mode, which will modify your card's performance, coolness, and noise level, as well as VRam usage, GPU speed and temperature. This is all conveniently controlled from your desktop, too. Some STRIX cards feature a switch on top for Dual BIOS that change the fan profile and performance - you can switch between Performance Mode and Quiet Mode with a quick flick.


UEFI BIOS Utility – Advanced Mode
01/29/2074 Monday 15:39
English
MyFavorite(F3)
Qfan Control(F6)
AI OC Guide(F11)
Search(F9)
AURA ON/OFF(F4)
My Favorites
Main
Extreme Tweaker
Advanced
Monitor
Boot
Tool
Exit
Extreme Tweaker\AI Features
Setup Parameter 176
P0 Frequency 5000 MHz
P1 Frequency 4700 MHz
Target Non-AVX Auto Adaptive Voltage minimum stable Loadline Level LEVEL 7
Target AVX Auto Adaptive Voltage minimum stable Loadline Level LEVEL 6
Target Cache Auto Adaptive Voltage minimum stable Loadline Level LEVEL 3
Package Temperature Threshold Auto
Regulate Frequency by above Threshold Auto
Cooler Efficiency Customize Keep Training
Keep Training
Stop Training
User Specify
Recalibrate Cooler
Cooler Re-evaluation Algorithm
Optimism Scale 100
[Keep Training]: Continuous evaluations will be performed on Cooler efficiency and updated accordingly.
[Stop Training]: Cooler efficiency evaluations will stop and current evaluated efficiency will be used.
[User Specify]: You can specify the Cooler efficiency manually and all predictions will be based off this manual setting.
Hardware Monitor
CPU/Memory
Frequency 3600 MHz
Temperature 38°C
BCLK 100.00 MHz
Core Voltage 0.924 V
Ratio 36x
DRAM Freq. 2133 MHz
DRAM Volt. 1.200 V
Capacity 8192 MB
Prediction
Cooler 128 pts
NonAVX V req for 5000MHz 1.305 V
Max nonAVX Stable 4556 MHz
AVX V req for 5000MHz 1.342 V
Max AVX Stable 4277 MHz
Cache V req for 4300MHz 1.109 V
Max Cache Stable 4400 MHz
Last Modified
EZ Tuning Wizard
EzMode(F7)
Hot Keys
Search on FAQ
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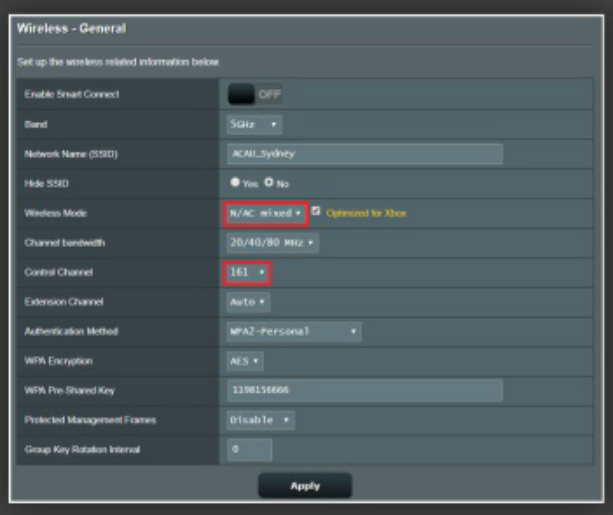
"ASUS KNOWS HOW IMPORTANT IT IS TO REAL ENTHUSIASTS THAT THEY CAN TWEAK SETTINGS, OVERCLOCK PERFORMANCE, AND CUSTOMISE THEIR EXPERIENCES."



You can also use your OC scanner from GPUTweak II to improve performance further if you're using a Pascal- or Turin-based GPU. The OC scanner runs a quick scan that determines the best performance you can get out of your card and gives you the option to apply its suggested settings after it runs. These functions give you easy control over what your card is doing, letting you tune your GPU based on how you're using your PC.

These options mean that you have that extra edge in your gaming, with complete control over how your games run.

MOTHERBOARDS

While Asus designs motherboards specifically for workstations and commercial use as well, odds are that you're after one designed with gaming in mind. The Republic of Gamers Maximus XI Extreme, for instance, should cover the needs of even the most hardcore, offering up 802.11ac Wi-Fi, ROG DIMM.2 dual M.2 expansion card, Aura Sync RGB LED, DDR4 4400MHz, four M.2, SATA 6Gbps, HDMI and USB 3.1 Gen 2. If you're looking into a pro gaming build, on the other hand, you might want to look at the ROG STRIX Z390-E Gaming, which offers top-speed protected networking and RAMcache for speeding up your game loads.

Once you've got the perfect motherboard installed, you can investigate AI overclocking to push your PC past its defaults. Thankfully, Asus' new auto-tuner makes things easier, meaning that the best settings is no longer a matter of tedious guesswork. By applying a heavy CPU load for a short period, Asus' proprietary algorithm determines your system's overclock potential and rates its cooling capabilities, giving you a Cooler Score and makes suggestions based on it.

AI overclocking can keep training your motherboard after its initial use. Important statistics like the temperature, power draw, and fan speed are continually monitored so that you have access to detailed information about how cool your PC's parts are staying. If your Cooler Score happens to shift, the AI tracking will adjust your overclock, meaning that you don't need to constantly monitor your machine to ensure that there are no issues with heat. This is a peace of mind issue, and it means that you can get the most out of your PC while not needing to worry that you're destroying it in the process.

Doing this doesn't even require the installation of additional software. Simply apply roughly five minutes' worth of heavy CPU load with software such as Prime95, OCCT, or Cinebench, and the built-in AI will have the recommended stable OC settings waiting for you the next time you are back in BIOS. Overclocking cannot be any easier.

ROUTERS

Once you've got the perfect PC, it's worth asking if you're using it under ideal conditions. Asus' range of routers are perfect for any gamer that wants to ensure the best experience and wants to rack up online kills in their shooters of choice without latency issues. For extended coverage, Asus recommends forcing your 5GHz band to any available clean "U-NII-3" channel (generally between channel 149 to 161) to utilise more radio power.

You can also turn on Asus' AI protection, which allows you to secure your home network from any external attacks it might face from anyone or anything that would seek to damage your network's integrity. Signing into WTFast GPN makes it easier to reach game servers and leads to faster ping (even if you're on a console), while the VPN Fusion function gives you extensive options over which VPNs you're using with which devices, which can help to prevent slowdown. If you're using Asus, you'll have more control over your PC and your Internet connection, without needing to become an overclocking expert or constantly monitor performance.

OPTIMISE YOUR UPGRADES

Identify bottlenecks and break through into pro-grade benchmarking By Zak Storey

Computers are funny things: a complicated collection of components, each working in conjunction with the rest to produce on-demand output. But as with any team effort, there is always a weak link in the chain.

As more and more people join the PC enthusiast community, it's easy to get swept up in the hype, and upgrade a very basic system with high-end componentry. And while that's not always a bad thing, it can lead to those weak links being stretched to breaking point, as top-end hardware makes its way into a system that wasn't designed to host it.

This can lead to bottlenecking, when one piece of hardware doesn't perform as well as it should, due to another component in the system being ill-equipped to handle the potential performance levels. As with the neck of a bottle, only so much can come through at once, so the power that's ready to be tapped is unused. It's usually easy to spot the part that is underperforming—a GPU, CPU, or RAID setup—but identifying which component is causing the bottleneck can be more difficult.

So, which are the most common problem parts? How do you identify them? And how do you break through that barrier? Read on to find out….

msi
CORSAIR
intel

Integral System Parts

The most common cause of bottlenecking is your platform and processor.

CPU

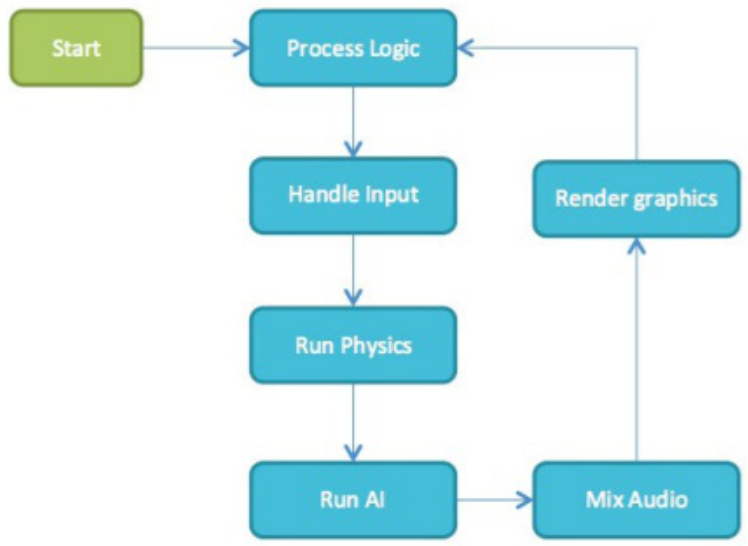
Bottlenecking is typically down to your processor. Your CPU processes everything from rendered in-game frames to memory storage requests, complex program processes, and more. It's an intricate part of the puzzle, and the easiest to become overwhelmed.

Most common bottlenecks, especially in games, are due to the processor not being fast enough to handle the data and processes thrown at it.

Six or seven years ago, most games required two to four high-powered cores to get the job done. Single-core was king, and the more instructions per clock your CPU could process, the better. Intel's well-founded single-core legacy comes from its early Nehalem architecture, which has seen no fewer than seven iterations since then, each capitalizing on improved single-core performance and support for newer hardware. Even, today Intel still holds that reputation, and despite the fact that Ryzen is now much closer to Intel's single-core performance.

CPU SYMPTOMS

The most common and obvious sign of a CPU bottleneck is low frame rates in games, even when using a powerful GPU. In short, your CPU is in control of the entire game. From a simplified point of view, it runs the process logic, handles your input to the game, runs the physics for that event, then calculates the AI's response, mixes the relevant audio given the triggers activated previously, and finally makes a request to the GPU to render the frame. At which point, it returns straight back to the process logic, and starts all over again. It does all this while running the OS and background apps, and moving data in and out of various frame buffers, DRAM, cache, and off the storage medium, back and forth between the GPU. To achieve a smooth 60fps, your processor has to manage all of that 60 times per second. In more complex titles, there are even more steps added to the game logic process chain, and as multiple events occur at the same time, it's easy to see how a low-end CPU struggles to handle a modern title.



▲ **A simplified version of what your CPU goes through to produce a frame.**

GAME CODING

How the processor performs in game, however, is dictated by the game devs. A CPU always operates at the same speed and frequency, processing the same number of instructions per clock every single second. If you send it a complex process to compute, filled with unnecessary jargon and redundant code, it takes up more of your processor's resources, so it takes longer to go through that chain we mentioned earlier, which in turn slows down frame rates.

SOLVING THE CONUNDRUM

How do you spot a CPU bottleneck? Typical symptoms include long in-game load times, slow texture loading, and lower frame rates than you'd expect, given the GPU you're using. On the flip side, you may notice seemingly high frame rates, but textures don't appear to render correctly, with horrendous levels of stutter and lockups.

To confirm this diagnosis, we need to do some testing and data collection. This requires a very in-depth benchmark, such as the one integrated into Assassin's Creed Origins or Tom Clancy's Ghost Recon: Wildlands, and a third-party system monitoring app, such as HWInfo or HWMonitor. Assassin's Creed features a benchmark HUD, which actively shows you how many cores are being utilized, and what percentage of load they're under, while also displaying you the maximum GPU load. Regardless, we're looking for the same info: CPU and GPU load.

If, for instance, you have a processor with two cores and multithreading—an old Intel Core i3, say—and all four of those logical cores are registering 100 percent load for the duration of your benchmark, with the GPU hovering around 60 to 80 percent, we can safely say the CPU is the bottleneck, because in an ideal world, the reverse would be true. This is what we call an absolute bottleneck, as you'll start to see in-game degradation, textures not loading, slow load times, and frame stuttering.

That said, you don't necessarily need all of your CPU cores running at 100 percent load to find yourself with a bottleneck; minor ones can occur due to slower single-core performance, as you'll see later with our benchmark results.

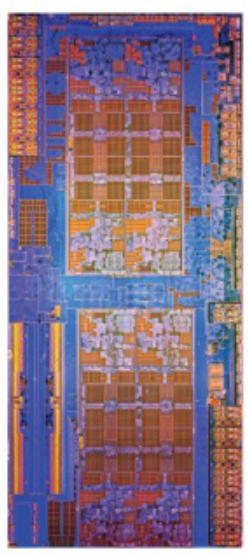
The differences are most notable at higher refresh rates, with higher powered GPUs, but they still exist at the low end. And if you play competitive FPS games, for instance, at 144Hz and above, at 1080p, single-core performance is still very much king.

CAN YOU STILL BOTTLENECK?

Although Intel's 10 percent incremental performance increases generation upon generation haven't exactly wooed anyone, almost a decade of them has led to single-core performance increasing by a staggering 93 percent since Sandy Bridge. Combine that with access to more cores as the market heats up, and what you're left with is quad-core $200 i3s pumping out nearly twice as much grunt as their siblings back in 2010.

And although graphics in the big story-driven AAA titles have improved in leaps and bounds, few developers take advantage of more than four cores. This is purely down to the fact that the majority of the market still sits on quad-core parts.

▼ **More cores don't always beat higher single-core grunt.**



Thanks for the Memory

How much is enough? What about frequency?

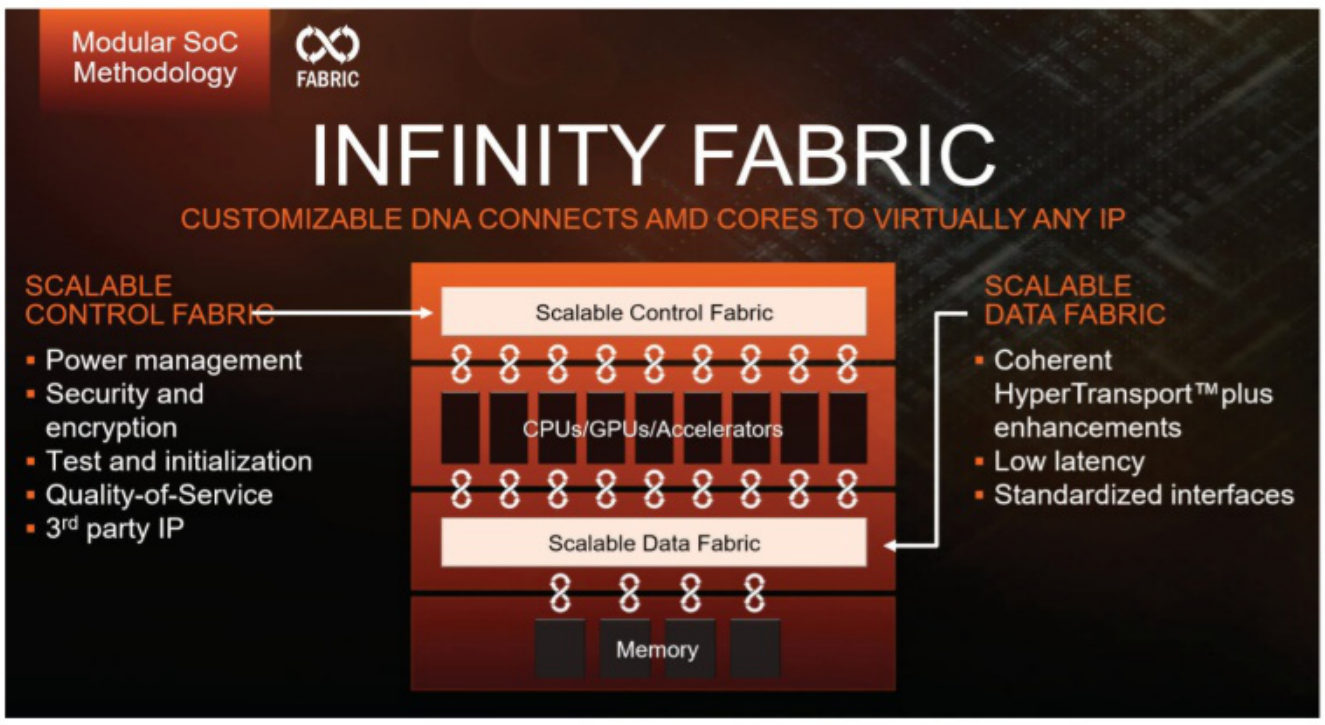
Memory is an integral part of any system, and it interacts with the CPU in a very interesting way. It's essentially a hyper-fast, volatile storage medium, designed to hold data that needs to be accessed more quickly than that found on non-volatile hard drives, yet using files that are larger than those that can be held locally on the internal CPU cache.

When it comes to processors, outside of rendering tasks or simulations that operate off large data sets, it's difficult for your memory to bottleneck your system. Most everyday tasks don't process or shift enough data fast enough for the bus between the DDR and the CPU to ever become truly saturated, or for the memory to be under 100 percent load all the time.

You can encounter bottlenecks when video rendering, as large amounts of data and imported video clips are transferred from the non-volatile storage to the DDR, then the CPU and GPU, but aside from that, memory speed (frequency, in this case), for Intel at least, matters very little.

INFINITY FABRIC

AMD's Ryzen architecture, on the other hand, does take advantage of increased memory speeds for flat single and multicore performance increases, because the interweaving fabric that connects each of Ryzen's core complexes together runs at the same frequency as the memory itself. This means that the higher the memory speed, the faster the Infinity Fabric runs, and therefore the faster each core complex can transfer data and instructions between the other complexes and cores in turn. That said, there are diminishing returns from increasing memory frequency with Ryzen parts—typically, anything above 3,200MT/s on the Ryzen 1000 series will fail to see any further improvement, while the Ryzen 2000 series increases that limit to 3,600MT/s.



▼ **AMD's Infinity Fabric thrives on higher frequency memory.**

DUAL-CHANNEL VS. QUAD-CHANNEL

Frequency? Bandwidth? Dual and quad-channel? What's going on? In reality, maximum performance is a combination of four factors: the base clock frequency at which the memory operates, the number of data transfers possible per clock (DDR means double data rate), the width of each channel or memory bus (64 bits), and the number of channels used to transfer data to and from the CPU.

Say we have a 16GB kit (2x 8GB) of dual-channel DDR4, with a base frequency of 1,600MHz. We can do the following calculation to figure out how much memory bandwidth we have. We take the 1,600 (MHz), break that down into Hz (1,600,000,000), and multiply it by the data rate (2) to get 3,200,000,000, aka 3,200MT/s (or 3,200MHz if you're in marketing). Multiply that by 64 (the width of each channel in bits), and multiply that by 2 (the number of channels), and we're left with the final figure in bits per second. Divide that by 8 for bytes, and it's 51.2GB/s, which is the maximum amount of data that can be transferred to and from your memory modules at any time. For quad-channel, you double that figure.

The important thing to note here is that no matter how many sticks of memory you have installed in your system, the CPU can only write or read from however many channels it supports at one time, so for mainstream platforms, that's two. You could have four sticks installed in a dual-channel system just fine, but all you're essentially doing is increasing the maximum memory capacity of your rig, enabling you to store more data in your DRAM—it's not faster than just running two.

As far as video editing is concerned, the more bandwidth you have the better, especially if you're working on 4K video and higher, because those files and frames are often stored directly in DRAM, and it's very easy to bottleneck a system that way.

Graphics Bottlenecks

The wonderful world of VRAM, and how a GPU does what it does.

Memory is also a vital component when it comes to rendering graphics, both with integrated and dedicated GPUs. It all comes down to the notion of a frame buffer. In short, the GPU cores found in both graphics cards and CPUs rely on the frame buffer to store rendered textures, which can be called upon, when required, for quick, smooth, and efficient rendering, and the piecing together of frames in game. For a standalone GPU, the card itself features its own dedicated memory, designed specifically with that one task in mind. These memory chips typically run faster than their DRAM counterparts, and have a wider bus, which allows for a larger amount of data to pass through at any given time.

For instance, an Nvidia GTX 1080 has a 256-bit bus, with its GDDR5X chips running at a base clock frequency of 5GHz (or 10GT/s), and can transfer up to 320GB/s of data to and from the memory found on the graphics card itself—and that's all off a single channel.

Integrated graphics run off a very similar system, with both Intel and AMD's latest APUs featuring far smaller capacity memory located on the CPU's integrated GPU.

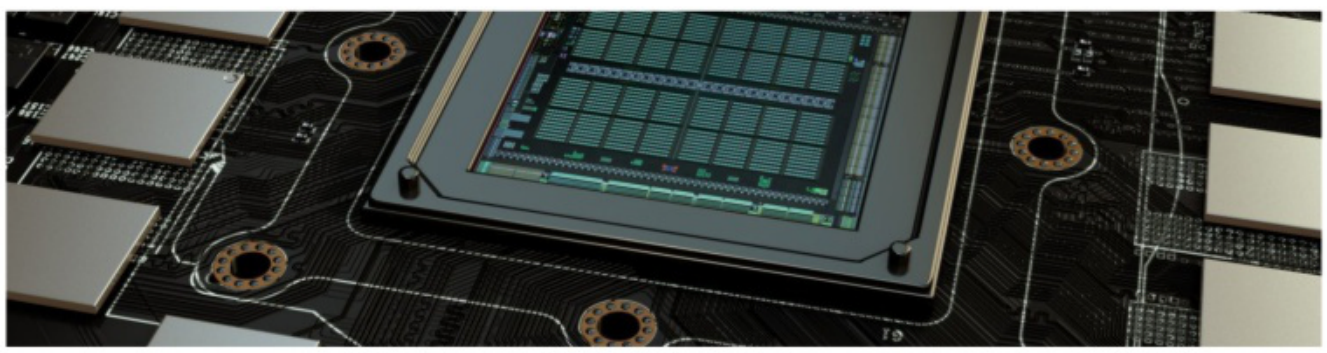
The big problem for GPUs, however, is when the total dedicated VRAM storage capacity becomes saturated. It's not the width of the bus that's the problem, but more the capacity not being big enough to hold all the high-definition textures and pre-rendered frames necessary to smoothly render the frames in the game you're playing. In this situation, the GPU offloads any remaining texture files on to traditional DRAM, which is far slower than its VRAM counterpart. These files have to be transferred across from the GPU to the CPU, and then to the DRAM, before going back again. This increases CPU utilisation, bumps up texture load times, and increases frame latency as the data has to go back to the GPU via the CPU. This is where you begin to get your memory bottleneck, and why, on occasion, you'll find GPUs with cores capable of driving games at two resolutions, often with multiple VRAM configurations.

▼ **VRAM operates at a far faster frequency, with a wider bus, than traditional memory.**

LOAD RATIOS AND 4K

When it comes to GPU core performance, resolution and frames per second play a big part in overall system load. Generally speaking, the higher the frame rate, the harder the CPU has to work to process all that information effectively, and the easier it is for your CPU to become the bottleneck in a system. As the resolution increases from 1080p to 4K, that load is then offset to the GPU, and the graphics core spends more time rendering each scene (due to that 300 percent increase in the number of pixels). Because of that, the load shifts away from the CPU and on to the GPU, and simultaneously frame rates fall.

This is important; because a GTX 1080 Ti and Core i3-8100 combo is more likely to work better at 4K than at 1080p, so far as bottlenecks are concerned.



OVERCOMPENSATING

Having read the above, you should now have some understanding of just how important it is to buy the right GPU for the resolution you want to take advantage of, and the games you want to play. Memory and GPU cores are typically well paired. A GTX 1060, for example, combined with 3GB of VRAM, is more than enough for 80 percent of most modern AAA 1080p titles, with 6GB of VRAM being enough to future-proof you for years, or just enough to scrape by on for 1440p.

The big problem, however, lies with the folk who drop the cash on a GTX 1080 Ti, only to then game at 1080p. Unless you're absolutely obsessed with playing first-person shooters at 200Hz and above, with super-low latencies, such a purchase makes little sense from a consumer standpoint. Even if you roll with the notion of it being part of a smart future-proofing decision, the reality is that HD textures are highly unlikely to reach 11GB in size any time soon, and even if they do, by that point 1080p will be positively antiquated technology in comparison to both the GPUs and the resolutions of the future.

4K shifts most of the load away from the CPU and on to the GPU instead.

Storage Chokes

Your choice of platform dictates whether or not you can run a RAID.

Storage solutions are the next biggy on our list of bottleneck conundrums, and the issue pretty much boils down to the introduction of the latest PCIe SSDs, from the likes of Samsung, causing problems for those interested in setting up multiple drives in RAID 0. Traditionally, when you wanted more speed from your system, the obvious way to do this was to take two hard drives—spinning platters or flash SSD—and set them into a redundant array of independent disks with striping. You'd take two drives, and force the data saved to be split in half and written to both simultaneously. Then you could read the original data from both drives at the same time, effectively doubling performance, in exchange for a little more vulnerability, because if one drive fails, half your data is gone.

PCIE SSD RAID 0?

The big question is: Can you do that with PCIe SSDs? The answer: Technically, yes you can, but you won't gain any performance out of it. At least, not from most mainstream platforms. The problem derives from how both Intel and AMD have configured the use of their chipsets and storage I/O, and it's all to do with the PCIe lane interconnects. Let's break it down.

Intel's mainstream platform takes advantage of what's known as a DMI (direct media interface). Briefly speaking, this is a direct connection between the CPU, the PCH/chipset, and the I/O storage devices in your system (SATA, USB, and M.2 SSDs). From Z170 onward, Intel has been using DMI 3.0, which is essentially four PCIe 3.0 lanes. What that means is that the maximum throughput from the chipset to the CPU via the DMI is currently 3.93GB/s (or 3,930MB/s).

All of a sudden, it's easy to see what's causing your bottlenecks when running twin M.2 PCIe SSDs in RAID 0, because there's simply not enough bandwidth to allow for a straight doubling of performance, as was possible with SSDs and HDDs through the SATA interface and DMI 2.0 (maximum throughput about 2GB/s).

AMD's Ryzen architecture runs things differently. The PCH to CPU interconnect actually only runs four PCIe 2.0 lanes, similar to Intel's original DMI 2.0, as opposed to DMI 3.0's four PCIe 3.0 lanes we see today. However, that's dedicated to onboard USB 3.1/0 and USB 2.0 devices. This is because although both Intel and AMD's processors reserve 16 PCIe 3.0 lanes directly for graphics solutions, AMD also reserves an additional four PCIe 3.0 lanes directly to the CPU for PCIe SSDs and SATA drives, with no interim chipset adding latency to the affair.

That said, it's still only four PCIe 3.0 lanes, and a 3.93GB/s max transfer rate between the CPU and its storage, meaning again, there's just not enough bandwidth.

▲ **Threadripper's minimum BS attitude to RAID 0 PCIe SSDs is something we can get behind.**

▼ **RAID 0 support is limited, depending on the platform.**

WHAT ABOUT THE HIGH END?

At the high end, both platforms change things up quite dramatically. As both teams field processors with more and more dedicated onboard CPU PCIe 3.0 lanes (Intel's top-end chip offers a fruity 44, while Threadripper's entire range throws up 64 in total), it is indeed possible to run PCIe SSDs directly off the CPU, as opposed to running them through the chipset and DMI.

Despite Intel having multiple PCIe lanes on its chips, it hasn't supported RAID on PCIe SSDs until very recently. With Skylake-X, it introduced VROC (Virtual Raid on CPU) for the first time, allowing PCIe SSDs utilizing those direct CPU PCIe lanes to theoretically form a RAID directly on the CPU itself. However, there's a few caveats to this. Firstly, you need a VROC key—this is a physical dongle that you plug in to the motherboard to enable the feature. It's not possible to buy these separately from an official retailer, because they're typically only bundled with specific motherboards and SSDs (although you can buy one from a third party for roughly $100-150). And once that hoop's been jumped through, you can also only use Intel SSDs for VROC, which limits you to Intel's Optane 760P SSDs, which are hardly mind-blowing when it comes to storage.

On the flip side, AMD's Threadripper series packs a whopping 64 PCIe lanes directly on the chip itself, allows you to RAID whatever you like directly on the CPU without any proprietary nonsense, and is realistically the most sensible platform, where you'll see sequential speeds bounce up because of it.

Testing time

Let's fire up some software, and perhaps a spreadsheet or two, and figure out where exactly your bottlenecks are.

CPU

There are a few obvious bottlenecks we're going to ignore, as they're processor limitations. For instance, video editing benefits from more cores and higher single-core/IPC. But the biggy is in game. Go to www.cpuid.com and download HWMonitor (dodge the Pro version), run that, and minimise everything aside from the "Utilization" section for your processor and graphics card. Here you'll see all your threads, and their current, minimum, and maximum utilization, along with your GPU utilization. Load up the gaming benchmark of your choice (Unigine's Superposition is a solid alternative at **https://benchmark.unigine.com**), then Alt-Tab back to HWMonitor, select the "View" drop-down, hit "Clear Min/Max," then go back to your benchmark, and hit "Run."

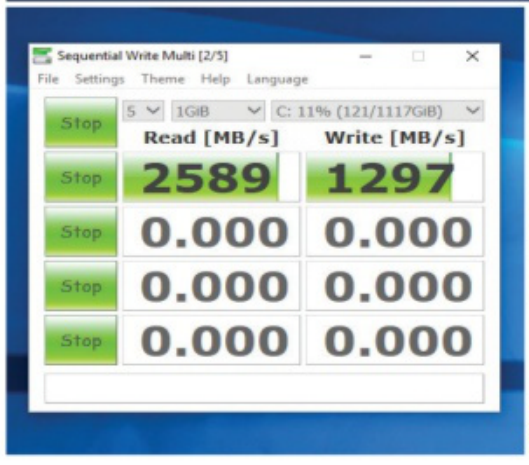
You're looking for whether your CPU load is at 100 percent across all threads while your GPU load is at about 60–70 percent. If it is, you'll want to look at upgrading that CPU to something with a little more grunt. We recommend a minimum of an Intel Core i3-8100, or a Ryzen 3 1300X.

▲ HWMonitor is a vital tool for any PC junkie.

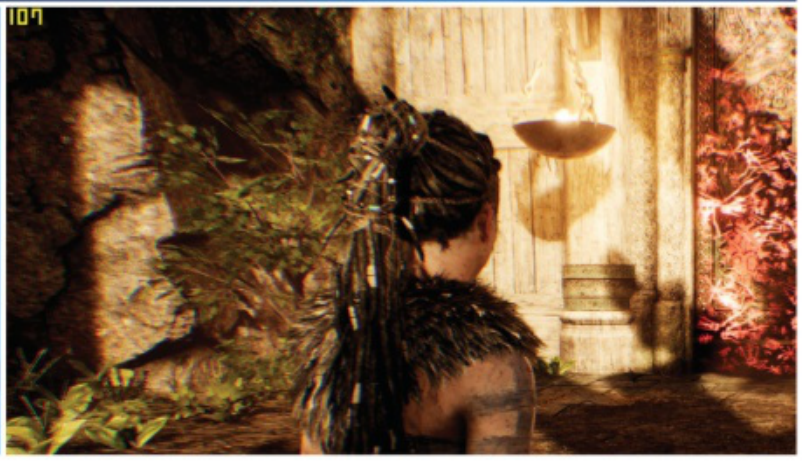
GPU

Again, the obvious bottleneck with the GPU comes from a lack of core performance for the resolution you want to play at. You want to hit around 40fps in game to have something of an enjoyable experience; 60fps is the sweet spot, but it's not the end of the world if some titles don't reach that—it's not suddenly unplayable. There's a ton of ways to see frame rates in game; some titles support it as an option, but if that's not possible, you can download a trial of Fraps (www.fraps.com), which includes a visual fps overlay to allow you to see your frame rate in the corner of the screen.

We can test whether a lack of VRAM is bottlenecking your system by using HWMonitor and the game you're having difficulty with. Keep HWMonitor open and those utilization windows up, and play the game you're having difficulty with. If you notice the memory is maxing out at 100 percent, either reduce the resolution of the textures, or opt for a newer GPU.



▲ Our favorite SSD testing utility by far.



▲ In-game fps overlays make figuring out performance woes far easier.

SSD

And finally, we have the wonderful world of solid-state bottlenecks. Unfortunately, as we've already discussed in depth, anyone who's running more than one PCIe SSD in something like a RAID 0 array—unless you're running those devices in a Threadripper motherboard, and have gone about extensively setting up the array for them—it's an absolute truth that you're bottlenecking both drives, while simultaneously increasing your risk of data loss. CrystalDiskMark is our go-to benchmarking software for this challenge, so head to h**ttps://crystalmark.info** to download the latest version of our favorite SSD benchmark, then it's simply a case of running the QD32 Sequential speed test on the drive or array in question to identify just how fast it's running.

If you're running multiple PCIe drives on any mainstream board, it may also be worth checking to see whether all your M.2 slots are running in PCIe mode, and not SATA—after all, you don't want a 3,000MB/s drive to be capped at 550MB/s because of the SATA interface.

Case studies

Let's fire up some software, and perhaps a spreadsheet or two, and figure out where exactly your bottlenecks are.

PART	
CPU	Intel Core i3-3240
Cooling	Stock
Memory	8GB (2x 4GB) DDR3 @ 1,600MT/s
GPU	2x GTX 970
Motherboard	Gigabyte GA-Z77X-UP5 TH
SSD	120GB Samsung 840 Evo
HDD	1TB Western Digital 7200rpm
PSU	550W Corsair TX550M

PART	
CPU	AMD Ryzen 7 1700 @ 3.8GHz
Cooling	Stock
Memory	32GB (2x 16GB) DDR4 @ 2,666MT/s
GPU	Nvidia GeForce GTX 1080
Motherboard	MSI X370 Gaming Pro Carbon AC
SSD	1x 512GB Samsung 970 Pro
HDD	1x 1TB Samsung 960 Evo
PSU	700W Be Quiet! Pure Power 10

PART	
CPU	Intel Core i9-7900X @ 4.7GHz
Cooling	NZXT Kraken X72 360mm AIO
Memory	8GB (2x 4GB) DDR3 @ 1,600MT/s
GPU	Nvidia Titan Xp
Motherboard	Asus Prime X299 Deluxe
SSD	1x 250GB Samsung 960 Evo
HDD	1x 1TB Crucial BX300 2.5-inch
PSU	1,200W Corsair AX1200i

THE ANCIENT GAMER

There are two major problems here, the first of which is the dual GTX 970s running in SLI. This forces the GPUs to operate in PCIe x8 mode, as opposed to a full-fat x16. Couple that with the fact you've got just a dual-core processor, and most games are immediately going to throttle even at 1080p.

The GPU solution is fine on its own for 1080p, but the problem lies with that processor. It would make sense to upgrade the motherboard and CPU to something with more cores and single-core grunt.

The second and possibly more alarming problem is the 550W bronze-rated power supply. By default, you should be drawing around 450W from the wall—even with this dual SLI setup—but only having 100W of headroom doesn't fill us with confidence if things spike under extreme load. Worst case scenario: The power supply can pop, and take parts with it. Best case: It just won't power on under those circumstances.

> By default, you should be drawing around 450W from the wall—even with this dual SLI setup—but only having 100W of headroom doesn't fill us with confidence

THE EAGER PROFESSIONAL

In this scenario, the end user has taken a single Ryzen 7 1700 and ramped it up to 3.8GHz across all 8 cores and 16 threads. Which is fine—the 1700 is more than capable of handling those kind of voltages and frequencies. However, the biggest problem here is something we haven't covered so far, and that's thermal throttling, which in its own way is a very specific form of bottlenecking.

In short, as the temperature gets too high, if your processor is stable, it immediately begins to downclock itself, to ensure it doesn't damage any of the silicon at its heart. You may think it's running at 3.8GHz, and it may very well be at startup, but as soon as you get in game, or start running some computational tasks, that frequency is going to drop, just to keep the chip safe.

On top of that, this rig has multiple PCIe SSDs installed. The Samsung 970 Pro for the OS is directly installed on to the motherboard, and will operate just fine utilizing those four dedicated lanes we spoke about earlier. The problem is the 1TB 960 Evo—although some motherboard manufacturers do allow you to run an additional PCIe SSD in an M.2 slot, they are usually forced to utilize the majority of the interconnecting lanes between the PCH and the CPU. In Ryzen's case, that's four PCIe 2.0 lanes, meaning maximum transfer rates of 2.0 GB/s. Not good.

THE EPEEN STREAMER

In our final selection, we have a combo designed to make any tech journalist flinch. The issue here isn't that obvious at first glance, but it all comes down to the motherboard and CPU combo, combined with that hefty overclock. Although the Core i9-7900X is aptly cooled by the 360mm AIO to an impressive 4.7GHz overclock, the problem lies with the VRMs on the motherboard. There's too much voltage being pushed through them, and not enough heatsink to provide them with sufficient cooling. In short, the mobo's BIOS is forced to reduce the voltage to keep temperatures within acceptable parameters.

Although the CPU may well register at 4.8GHz, and be operating at 100 percent utilization, the actual performance can be even lower than stock in some cases. The best way to spot this is by installing HWInfo, and analyzing your VRM temperatures—anything above 110 C when under load is bad news. Run Cinebench R15 at stock and then at your overclock settings, and if you're noticing a drop in score without a drop in utilization or registered clock speed, you know it's the VRMs causing the issue.

There are two solutions: You can either drop back on the voltage, or opt for a beefier cooling solution, one that directly cools the VRMs. EKWB and some other aftermarket liquid-cooling companies offer full-cover monoblocks for both the VRMs and the CPU on most mainstream motherboards.

Bottleneck results

Exactly how do different setups affect your performance?

HOW WE TESTED

Obviously, we no longer have a lot of the old hardware we've featured below, so much of this is synthetic, rough benchmarking, utilising a Core i7-8700K. The theory is fairly simple: We found our old Cinebench R15 single-core figures for everything back to Sandy Bridge, and declocked the Core i7-8700K to the point at which we achieved similar, if not identical, scores to the old processors. At that point, we disabled a variety of cores and/or Hyper-Threading, depending on the configuration of the part we were trying to emulate at the time.

Other than that, our test rigs included 16GB of DDR4 for our mainstream platforms, operating at 3,200MT/s, and 32GB of DDR4 for our X399 and X299 RAID testing. Our PCIe SSDs of choice consisted of dual Samsung 960 Pro 512GB SSDs, operating through onboard M.2 slots, or Asus's included ROG Zenith adapter.

As for mobos, our Intel games and RAID testing featured MSI's Z370 Godlike Gaming. For Ryzen RAID testing, we plumbed in our recent MSI X470 Gaming M7 AC. For our Intel RAID testing, we took advantage of the Asus Prime X299 Deluxe, and for Threadripper RAID testing, we grabbed our trusty Asus X399 ROG Zenith Extreme, in combination with the included PCIe SSD adapter.

All games were tested at the Ultra preset, with HD textures. 3DMark's Sky Diver was run at default for 1080p, and then adjusted to 4K for the 4K testing. The DNC runs for the Core i3-2120 in Assassin's Creed: Origins were actually to do with how the benchmark performed. It genuinely did complete each run, but there was massive lag in loading textures, with wire meshes and HD textures taking an eternity to load—if at all. As the scenes became more complex, frame stuttering occurred, and although the frame rate remained high, it was clear that this isn't how the benchmark was meant to run. PC

"We found our old Cinebench R15 single-core figures for everything back to Sandy Bridge, and declocked the Core i7-8700K to the point at which we achieved similar, if not identical, scores to the old processors."

Intel Core i7-8700K Clock Speeds & Core Setup

Indictaes Best Result

	Cinebench R15 Single-Core (Index)	Frequency/Active Cores
Intel Core i3-2120	80	3.1GHz/2+2
Intel Core i5-3570	132	3.2GHz/4+0
Intel Core i7-4790K	169	3.7GHz/4+4
Intel Core i3-8100	154	3.6GHz/4+0
Intel Core i7-8700K	190	N/A

SSD RAID 0 Testing (2x Samsung 960 Pro 512GB)

	CDM Seq Read	CDM Seq Write	CDM Random 4K Read	CDM Random 4K Write
Intel Core i7-8700K	3,456 MB/s	2,170 MB/s	49 MB/s	138.3 MB/s
AMD Ryzen 7 2700X	3,066 MB/s	2,006 MB/s	49 MB/s	123.7 MB/s
Intel Core i9-7900X	3,157 MB/s	2,165 MB/s	43 MB/s	183.32 MB/s
AMD Ryzen 7 Threadripper 1920X	5,912 MB/s	3,859 MB/s	38 MB/s	180.2 MB/s

> The DNC runs for the Core i3-2120 in Assassin's Creed: Origins were actually to do with how the benchmark performed. It genuinely did complete each run, but there was massive lag in loading textures, with wire meshes and HD textures taking an eternity to load—if at all.

Nvidia GeForce GTX 1060 3GB (avg fps) @ 1080p

Indictaes Best Result

	Assassin's Creed Origins	Middle Earth: Shadow of War	3DMark Sky Diver
Intel Core i3-2120	58 (DNC)	74	17,091 (index)
Intel Core i5-3570	54	74	21,563 (index)
Intel Core i7-4790K	58	73	26,943 (index)
Intel Core i3-8100	57	74	23,182 (index)
Intel Core i7-8700K	58	72	32,900 (index)

Nvidia GeForce GTX 1060 3GB (avg fps) @ 4K

	Assassin's Creed Origins	Middle Earth: Shadow of War	3DMark Sky Diver
Intel Core i3-2120	24	26	11,310 (index)
Intel Core i5-3570	24	26	15,632 (index)
Intel Core i7-4790K	24	26	17,098 (index)
Intel Core i3-8100	24	26	16,581 (index)
Intel Core i7-8700K	24	26	17,033 (index)

Nvidia GeForce GTX 1080 Ti 11GB (avg fps) @ 1080p

	Assassin's Creed Origins	Middle Earth: Shadow of War	3DMark Sky Diver
Intel Core i3-2120	65 (DNC)	92	19,286 (index)
Intel Core i5-3570	65	119	27,547 (index)
Intel Core i7-4790K	84	120	37,042 (index)
Intel Core i3-8100	67	122	29,496 (index)
Intel Core i7-8700K	98	123	49,871 (index)

Nvidia GeForce GTX 1080 Ti 11GB (avg fps) @ 4K

	Assassin's Creed Origins	Middle Earth: Shadow of War	3DMark Sky Diver
Intel Core i3-2120	54 (DNC)	51	11,066 (index)
Intel Core i5-3570	49	51	16,303 (index)
Intel Core i7-4790K	51	51	22,582 (index)
Intel Core i3-8100	52	51	17,340 (index)
Intel Core i7-8700K	52	51	31,383 (index)

The home of technology

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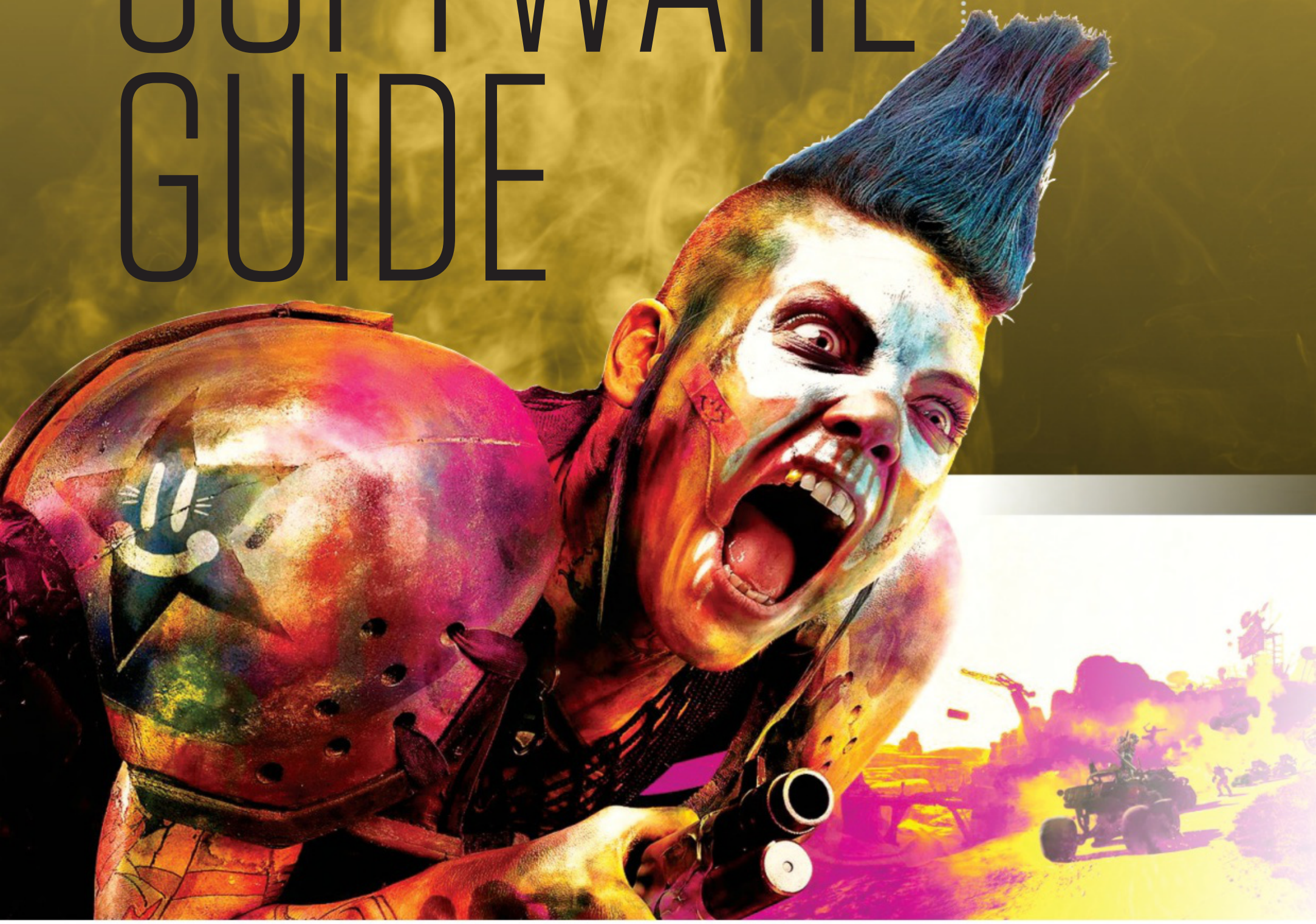
2019 SOFTWARE GUIDE

COMING UP

GAMES FOR 2019

p. 90

From heavy gunfire to forest spirits, here are our top tips for 2019 By Ian evenden.



THE BEST FREE PC SOFTWARE

p. 62

Tool up your PC for less with 39 essential gratis apps.

PLAY WINDOWS GAMES IN LINUX

p. 70

Discover how to get classic Windows games working in Ubuntu with Nick Peers.

SPEED UP WINDOWS

p. 76

Give your PC a burst of speed with this collection of tools to tweak, optimise, and reinstall Windows.

PLAY CLASSIC GAMES WITH DOSBOX

p. 86

Get your retro on, with Nate Drake.

THE BEST FREE PC SOFTWARE

Tool up your PC for less with 39 essential gratis apps.

Free software drives the PC industry. Paid-for packages might seem to be the better option in general (and if you're in industry, you'll need the professional support options that come from paying up), but it's the no-bucks-down applications that make life as an everyday PC user worth living.

We have three things to thank for the delicious software cornucopia that we've spread on the table today. First, the dedication and skill of the open-source community, predominantly those propping up the Linux world. These guys see a problem, they find something they want to do, and just go ahead and make it, offering up the software—and the building blocks that put it together—to the world when they're done. Thanks, folks. You rock, and you make the next generation of software better.

Second, we must thank the power of competition. Take web browsers: Had one tech big boy not stuck his finger in the Internet pie, chances are the rest of them wouldn't have followed suit in a bid to do things better, and taste that sweet, sweet market share and goodwill. Their generosity might be tinged with a combination of industrial malice and "you are the product" data collection, but sometimes you pay for your software in something other than hard cash.

Thirdly, and perhaps a little ironically, good old capitalism has a big role to play in the existence of the best free software. Some apps are made as alternatives to software that people resent having to pay for. Some are a free sample, a tantalizing just-useful-enough morsel to encourage you to invest in the whole meal. Whatever the reason, you get something awesome, and you don't have to pay a cent.

So, let's go ahead and make your life better by making your PC more capable. Let's get you set up to try new things, to create more, to break down format boundaries, to enjoy yourself. Let's go free: We've trawled the web, canvassed our colleagues, and batted away a host of competitors to compile this guide to the absolute best free software for Windows and, in many cases, Linux, too.

And while, yes, we are a gaming focused magazine, it goes without saying that when you build a new PC, you're going to need software. This is all just part of the process...

ALEX COX

Media

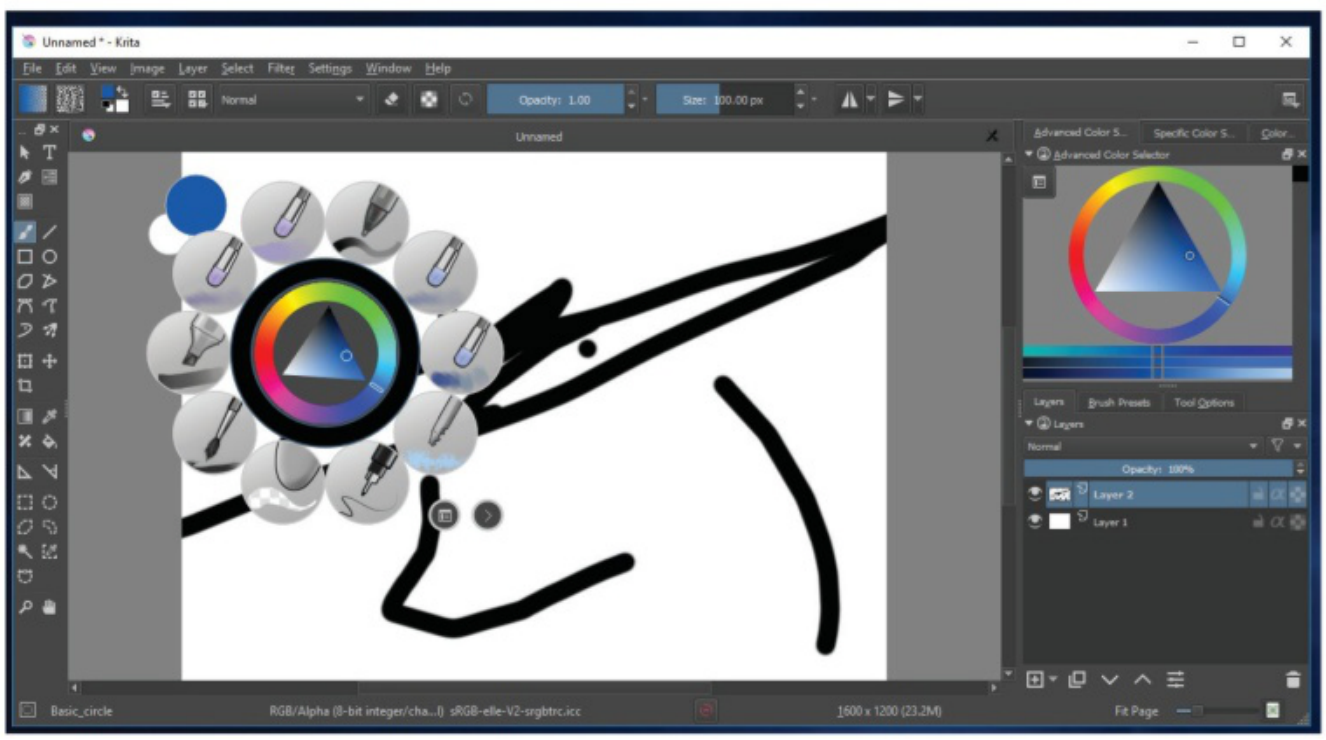
▶ VLC Media Player can handle pretty much any media format you care to throw at it.

1 PHOTO EDITING GIMP

About as Photoshop as you can get without actually shelling out a small fortune to use Photoshop itself, Gimp is densely packed with features, and capable of a massive array of photo manipulation and artistic endeavors. It's also far more refined than it was a few years ago, with the frequent crashes of yesteryear all but gone. Only the slightly janky interface remains to remind you that this is open-source software.
www.gimp.org

2 NATURAL PAINTING KRITA

Now 20 years old, Krita is a natural painting toolbox, perfect for everyone from artists to cartoonists, and beyond. It includes art essentials such as stabilized brushes, a pop-up palette, a wrapping texture mode, as well as a full animation interface. There are nine individual brush engines, each customizable and organizable to help you grab the right tool fast. Pick up the paid-for Gemini version on Steam (US$9.99) if you're rocking a convertible tablet and want to support the project.
http://krita.org



▼ Allow your inner artist to express themself with veteran painting app Krita.

3 VIDEO EDITOR LIGHTWORKS

If you're after pro-level video editing, Lightworks—legitimately used to cut proper Hollywood movies, such as The Wolf of Wall Street—is an incredible choice for the grand sum of zero bucks. You're restricted to 720p output on the free tier, but everything else is present and correct, from advanced non-linear editing to a whole host of color grading and effects tools. The learning curve is steep, but there's a vibrant community ready to help if you need any pointers.
www.lwks.com

4 MUSIC PLAYER MUSICBEE

No matter how large your music library is, MusicBee can handle it, with a tiny RAM footprint that makes this handsome skinnable player/manager perfect for even the lowliest laptop. You can tweak your sounds with surround upscaling, ASIO and WASAPI support, and a 15-band equalizer, and even make use of those crusty old WinAmp plugins if you need more. It'll even properly tag and fully organize that trashpile you call an MP3 collection....
http://getmusicbee.com

5 YOUTUBE DOWNLOADER FREEMAKE VIDEO DOWNLOADER

Downloading from YouTube isn't strictly kosher, but nothing's permanent on the Internet's foremost demonetization platform. It pays to be prepared if there's a video you can't do without—particularly if your data plan won't cover streaming your kids' favorite weird Spiderman/Elsa escapades when you're desperate for them to be quiet for two seconds. Freemake's multithreaded app is super-simple, super-fast, and it can suck down YouTube vids as well as content from Vimeo, Facebook, and beyond.
www.freemake.com

6 AUDIO EDITOR AUDACITY

Active development means that this audio stalwart has recently seen a bunch of new features added, and there are more on the way. Not that it necessarily needed much changing: Despite a rather, let's say, rugged interface, Audacity's power for multitrack audio manipulation is unsurpassed in the free bracket, and it's an immensely stable way to record from a microphone, too. Of course,

> "Gimp is densely packed with features, and capable of a massive array of photo manipulation and artistic endeavors."

now that it can natively play MIDI files, you'll be too busy looping canyon.mid to get any fresh recording done.
www.audacityteam.org

7 VIDEO PLAYER
VLC MEDIA PLAYER

VLC is brilliantly honest free software. When its creators were offered tens of millions of dollars to slather the app in ads, they refused—it's open source, proud about it, and the envy of the media player world, thanks to its solid compatibility with just about every media format. It can even handle streams on several protocols, and it's fully extendable. That said, everything important is on board from the start—no codec packs required.
www.videolan.org

8 STREAMING AUDIO
SPOTIFY

Despite the fact that it's cavorting around an increasingly competitive streaming playground, Spotify is still king of the jungle gym. It has the biggest library, the best interface, and its OGG-format files sound all but flawless, despite its lack of official high-res audio support. Admittedly, the ads can be a little repetitive and heavy handed if you don't shell out for a paid-for account, but that's the price of free.
www.spotify.com

9 VECTOR IMAGE EDITOR
INKSCAPE

You don't have a huge amount of choice if you need to create scalable vector graphics on a budget. You could shell out for a subscription to use Adobe Illustrator, or you could download the highly mature and feature-filled Inkscape. There's not really a happy in-between. Good job, then, that Inkscape is so capable, with support for blurring, gradients, multi-path editing, and exporting in every format you could possibly need.
http://inkscape.org

10 VIDEO MANIPULATION
HANDBRAKE

When you need video in one format but it's stubbornly in another, you need to transcode. Handbrake supports a massive list of formats on input and output, with profiles included for a host of common devices, and it's happy to convert frame rates and add effects on the way. Its key feature, though, is batch processing: Drop a collection of videos in, set it off, and it'll tell you when it's filled a folder with your freshly converted media.
http://handbrake.fr

Gaming

11 VALVE STEAM

Frequent sales, a massive indie library, and an early access program that gets you into new games before they've been officially released characterize Valve's store—but it's the little extras, such as the vibrant community, the Steam game overlay, and the Steam Workshop for mod content, that really make it. Steam has changed what gaming really is on the PC. Keep an eye on the store to find regular free weekends of popular games, which get you unlimited access for a limited time.
http://steampowered.com

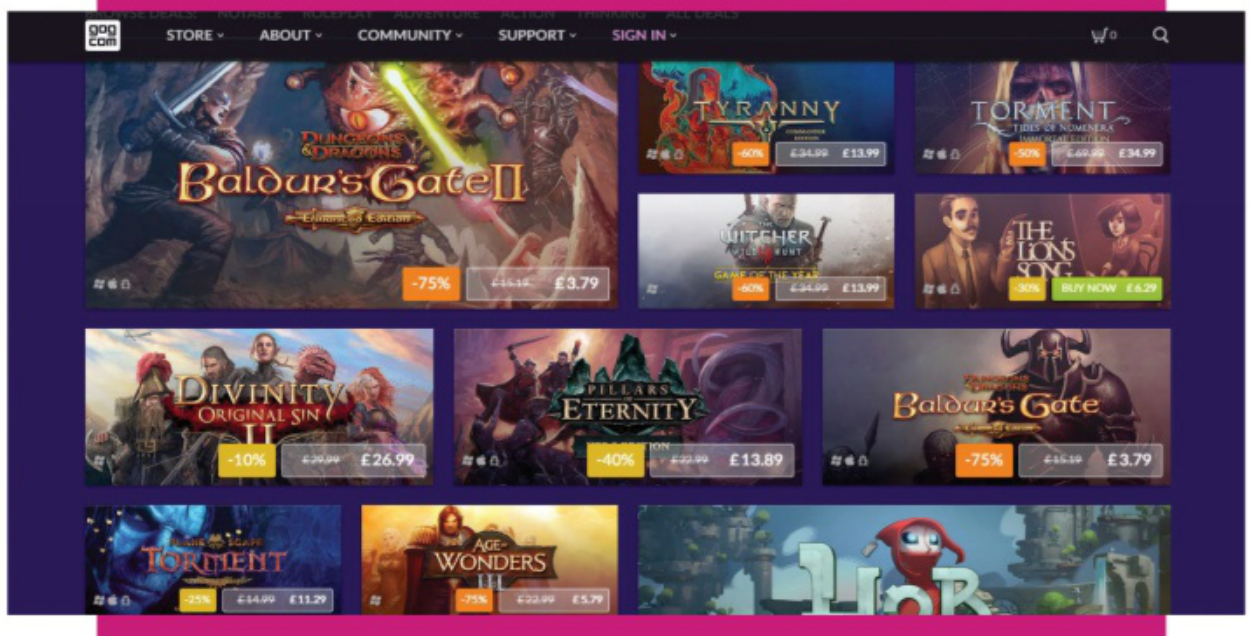
12 EA ORIGIN

Steam's publisher deals don't extend to every producer of AAA titles, and if you want in on EA's library, you need to use Origin. Whatever you might think about the gaming monolith's practices, Origin is a convenient way to manage your gaming, and get going with multiplayer action. Check the "On the House" section for a regular rotating selection of freebies, which you can add to your library forever, and take advantage of the trials to get time-limited access to hot new games.
www.origin.com

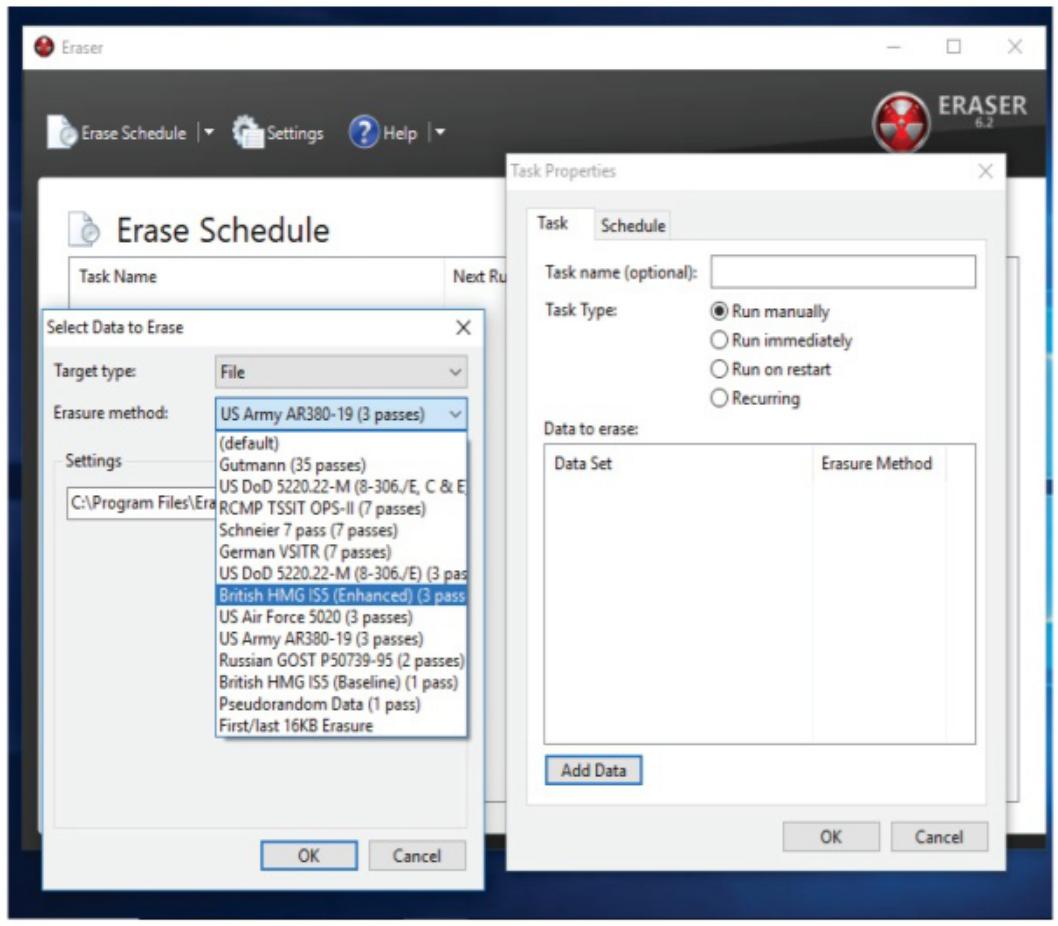
13 GOG GALAXY

If you're more inclined toward the old-school end of the gaming spectrum, GOG's selection of rigged-for-modern PC classics and the occasional new release are reasonably priced and almost always worth checking out. Galaxy is its desktop client, which makes finding and installing your favorite DRM-free titles quick and easy; if you're on board with GOG's philosophy and truely love old games, you should get on board with Galaxy.
www.gog.com/galaxy

▼ GOG features a great selection of DRM-free games, especially older titles. I just wish their social media team weren't dicks...



Security & Protection



▶ **Want to make sure those files you deleted are gone for good? It's time to turn to Eraser.**

14 SOFTWARE REMOVAL
PC DECRAPIFIER

Whether you're cleansing a new PC of its preinstalled bloatware or trimming down an existing machine to get rid of the stuff you really don't need, PC Decrapifier does the job fast, and it makes it easy. No other package is quite as informed on the awful software that manufacturers so thoughtfully include, and how safe it is to excise it—while you won't use it often, this is definitely one of those portable apps you'll want on your USB toolkit stick.

www.pcdecrapifier.com

15 SYSTEM CLEANING
CCLEANER

Windows is, among its many other jobs, like a cut-price janitor. Sure, it puts on a good show: It's packed with tools, and it claims they'll scrub your OS clean, but it's lackadaisical. It doesn't go as far as it could, and it often leaves filth around the edges. For the rest, you need something heavy, such as CCleaner, which can do away with Registry artefacts, files left over after uninstalling, and much more.

www.piriform.com

16 VPN
TUNNELBEAR

There are stacks of free VPNs out there, but never underestimate the importance of trust when it comes to something that's purportedly there to protect your web traffic—you need to know you're safe, not just funneling your entire bitstream through a criminal server. Cuddly ol' TunnelBear can be trusted, and it's completely uncomplicated: It just works. It's fast, it's solid, and the 500MB monthly free bandwidth should see you through all your secure transactions.

www.tunnelbear.com

17 ANTIVIRUS
BITDEFENDER ANTIVIRUS

Whichever way you slice it, however careful you may be, you can't get away without having antivirus installed. If you're going free, pick something with low system load, minimal amounts of notification spam, and a decent engine behind it. Bitdefender's latest update fits the bill—it's ultra-effective against malware, and extra light on resources, with a simple interface that just gets on with the job. Try Avira instead if you'd like a touch more control.

www.bitdefender.com

18 ANTI-MALWARE
MALWAREBYTES FREE

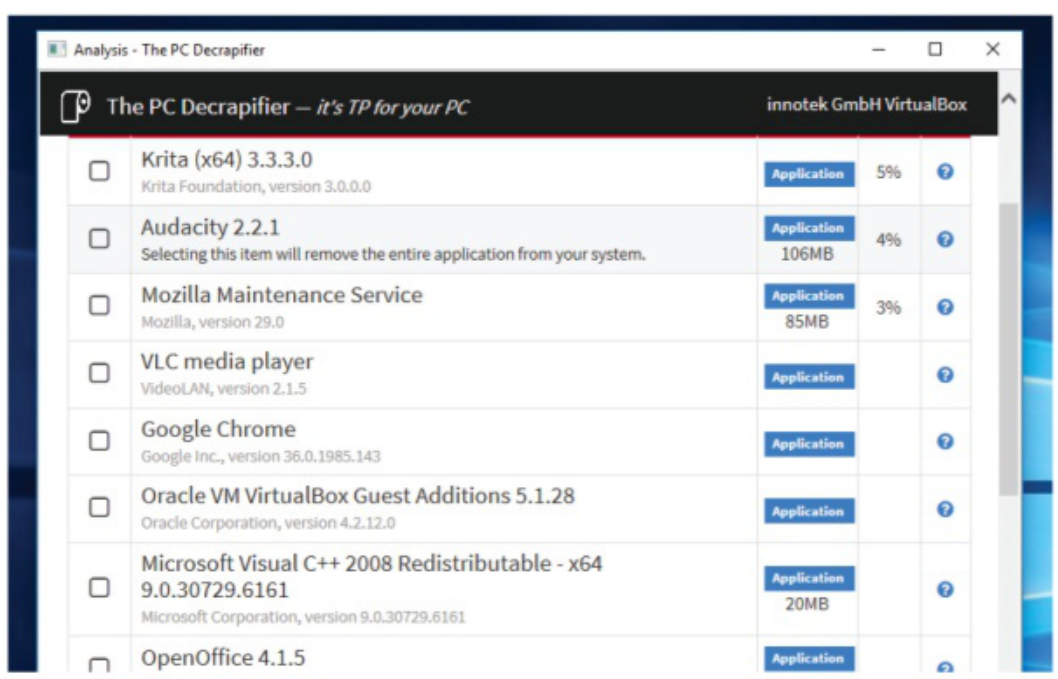
Admittedly, Malwarebytes' free tier doesn't do a huge amount—it's not a preventative, it won't steer you away from the seedier corners of the web, and it can't do anything about zero-day malware threats, unless you pony up some cash. What it does, though, is precisely what you need it to: Run it once you think you've fallen foul of some terrible malware threat, and it'll kill that pesky infestation until it's well and truly dead.

www.malwarebytes.com

19 PASSWORD MANAGER
DASHLANE

If you've never used the same password for multiple sites because you don't trust your memory, you're in the minority, and if you came up with that password yourself, chances are it's insecure in some way. Using Dashlane does away with the fallibility of the human brain. Remember one master password, and you need never even know the complex, nigh-unhackable passwords it automatically generates and types into web forms on your behalf—even Dashlane itself doesn't know them.

www.dashlane.com



▶ **PC Decrapifier jettisons the junk from your system—essential for new PCs.**

20 FILE DESTRUCTION
ERASER

You're probably already aware that deleting a file doesn't actually delete it. It's not until its little corner of drive space is reused that its data actually goes away, and even then there may be some trace of it left behind to be forensically recovered. Eraser ensures that those files you want well and truly removed are fully destroyed, using specially selected patterns of bytes over multiple passes to remove any digital memory of those files ever existing.
http://eraser.heidi.ie

21 SYSTEM PROTECTION
UNCHECKY

Probably the most common cause of malware infestation is inattention—clicking through a seemingly innocent installer, accidentally skipping past the page where it offers to install a brilliant browser toolbar, cursing yourself afterward. Unchecky doubles up: It unchecks those cheeky checkboxes (as you might expect from its name), and also sniffs out untrustworthy installers, warning you when you're about to accept an offer of questionable value.
http://unchecky.com

22 FILE RECOVERY
RECUVA

It doesn't matter if you've accidentally deleted a file, formatted a drive, or suffered some sort of horrific crash, Recuva can take a good stab at analyzing your drive, and getting your data back in one piece. It's not infallible, but if you have the time (and your hard drive has enough life left in it) to let it run a deep scan, you're more than likely to see results. It'll also do a secure overwrite, if you're looking to do the opposite.
www.piriform.com

23 BACKUP
EASEUS TODO BACKUP FREE

Selective, automatic, and easy. EaseUS's solution to backup is probably the most sensible we've seen. You can plug in an external drive (or point it at a NAS), and just set and forget—it periodically creates an incremental backup of your selected folders (or those it's chosen using its smart backup feature), without any more involvement from you.
If you want to take a more specific backup, you can, and restoring later on is incredibly easy.
www.easeus.com

Web Browsers

13 GOOGLE CHROME

Whatever you might think of Google, its browser—and the open-source Chromium browser that it's built upon—deserves its place at the top of the tree. It makes big demands on your RAM, but this is because it keeps every one of its tabs in its own memory space, meaning a crash in one window won't kill any of the others. There's a massive extension library ready to go, so you can browse exactly as you'd want to—although not every extension is worth the bits it's made of....
www.google.com/chrome

13 FIREFOX

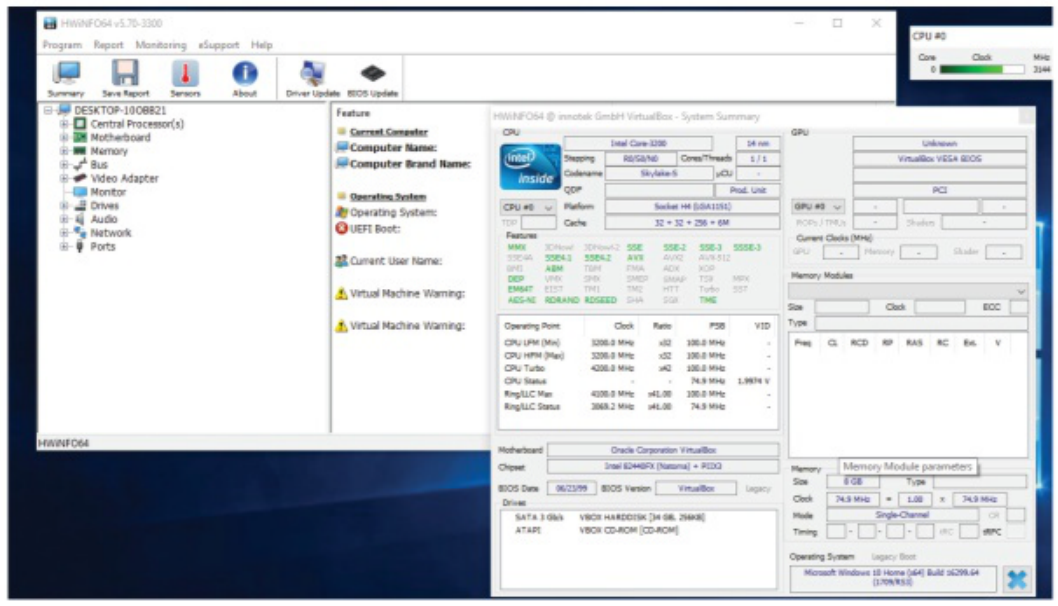
Far better than it was before it fell off the top spot, Firefox is now a highly efficient browser that's kinder on your RAM than Chrome, and—depending on your browser habits—potentially more stable, too. Running modern Firefox is a speedy experience, and if you're looking for privacy, you can do a lot more by default than Chrome's incognito mode—the anti-tracking features Mozilla has packed in are perfect for those desperate to leave a light footprint on the web.
www.mozilla.com

13 VIVALDI

You might place Opera in the number three free browser slot; we're going for Vivaldi, the browser that formed from disillusion with Opera's practices. It's a truly modern browser, using the same rendering engine as Chrome, and many of the key features of Opera, while tacking on a host of note-taking, tab-managing, experience-modifying features. There's a dedicated community driving the Vivaldi project on, and you can even use certain Chrome extensions.
http://vivaldi.com

▼ caption caption caption caption caption caption caption caption caption caption caption

System utilities



HWiNFO64 enables you to get to know your PC intimately, and pinpoint potential problems.

27 PDF READER
SUMATRA PDF

Adobe needn't have the monopoly on PDF reading. The format is far more widespread than it once was, and there are smaller, faster, and more versatile readers than, er, Reader—SumatraPDF being the best among them. It has a deliberately simple UI, because you're meant to be focused on reading, rather than clicking buttons, and also includes full support for rendering most mainstream ebook and comic book formats, as well as XPS and DjVu files.

www.sumatrapdfreader.org

28 EMAIL CLIENT
EM CLIENT

One of the cleanest email packages around, working with POP3, SMTP, and every other email delivery tech out there, eM Client's free version only really restricts the number of accounts you can use—every other feature matches up to its pro tier. This includes PGP integration, so you can securely sign or encrypt your messages, along with advanced contacts management, importing from other email apps, and a chat client that supports most common IM protocols.

http://emclient.com

29 FILE SYNCHRONISATION
DROPBOX

Keeping files synched between your many PCs and an online drive is a simple way of staying organised and safe, and it's not without its options. Google Drive, Microsoft OneDrive, Box, even Mega, they all give you a local folder that automatically mirrors one online. We favor Dropbox for this task, mainly because it feels like the most responsive and sensible way to magically clone your stuff. It's what DropBox was built to do—limited storage space be damned.

www.dropbox.com

30 MEDIA BURNER
CDBURNERXP

Optical media is a progressively more marginal form of storage, but it ain't dead yet, and the flexibility to do more than Windows' own built-in burning tools is essential. CDBurnerXP, which shows its lineage in its name, can burn it all—you can even use it to write HD-DVDs if you can find the hardware—and it can create and convert ISO files, too. Perfect for backing up backups.

http://cdburnerxp.se

31 MESSAGING
FRANZ

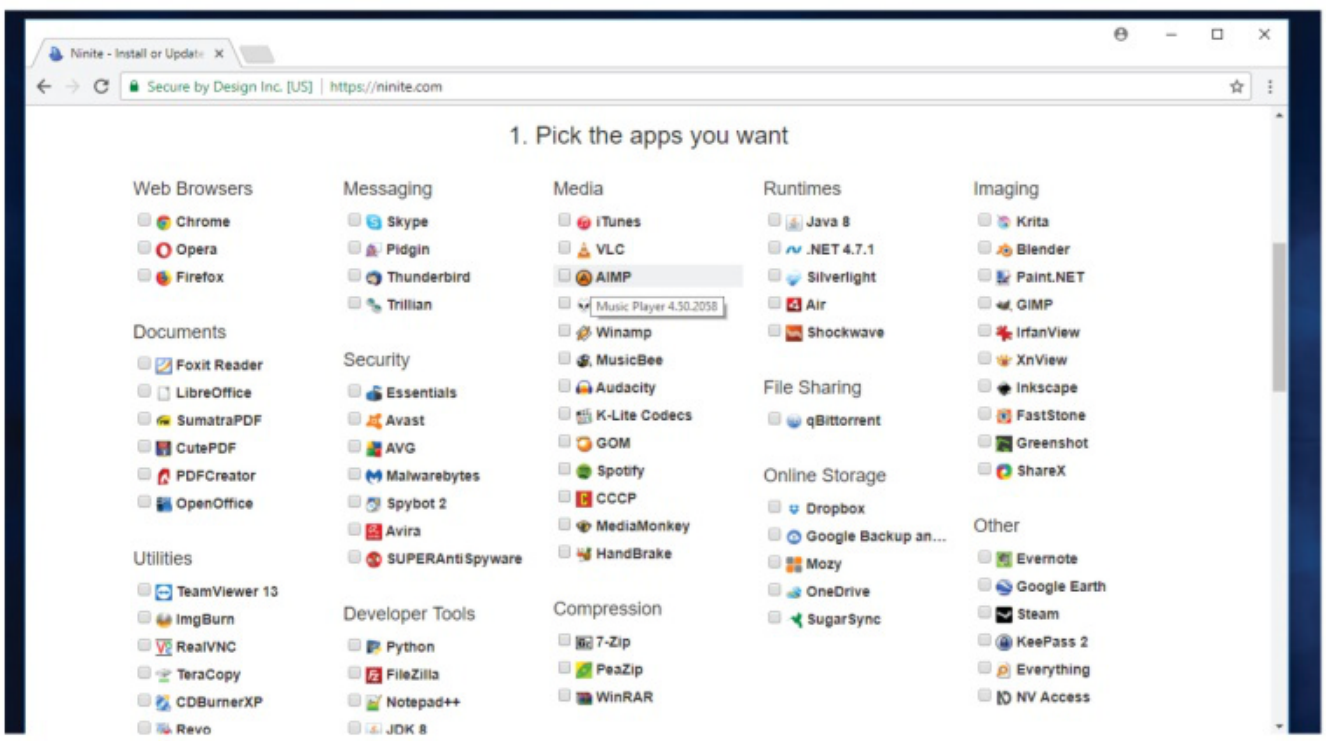
Franz doesn't actually offer its own messaging system, but it does serve up just about every other protocol. Configure your Franz account, add the services and usernames you want to use, and they're replicated on whatever machine you log on to next. Get your Slack, your Hangouts, your Skype, and even WhatsApp all in one place, and stop shunning that one person who won't move to the network the rest of your friends use.

http://meetfranz.com

32 NOTES
EVERNOTE

The great benefit of being the biggest name in your field, as Evernote surely is, is integration. So many other web services tie into it that you often don't need to make notes directly—just chuck the content you're interested in over to your Evernote, and it's there when you want to remember, organise it into notebooks, and otherwise make use of it later on. You can sync the basic free account with two devices.

http://evernote.com



Set up a system with ease, and let Ninite handle the job of installing free apps.

> If you're putting together a new machine, and you want it packed with free apps, Ninite can supply them—including many of the apps featured here—in one handy installer.

33 UTILITY SETUP
NINITE

Efficiency is the name of the game where Ninite is concerned. If you're putting together a new machine, and you want it packed with free apps, Ninite can supply them—including many of the apps featured here—in one handy installer. Just check the boxes on the site, download your custom executable, and fire it off to get the latest versions of the most popular applications installed with one click. No choices, no options, just clean installs of your favorite stuff.
http://ninite.com

34 VIRTUAL MACHINES
VIRTUALBOX

It's sort of remarkable that VirtualBox is free, particularly since it's owned by a company as large as Oracle, but the frequently updated virtual machine environment is essential if you want to cobble together sandboxed Windows installs, trial Linux distros, or do all kinds of shenanigans that it might be useful to roll back or keep separate from the rest of your PC. It's highly configurable, and you can even set up your own virtual networks.
www.virtualbox.org

35 SYSTEM INFO
HWINFO64

If you have a problem with your PC—or even if you don't—it's useful to find out exactly how it's operating. HWiNFO64 is a diagnostic tool that can serve up everything from a brief overview of your system's components to a deep dive into the minuscule operations of your PC. You can also use it for real-time monitoring, keeping an eye on the status of problem components, and predicting failure based on its findings.
www.hwinfo.com

36 COMPRESSION
7-ZIP

We find it pretty amazing how many people have the never-ending free trial of WinRAR installed when 7-zip does the job of archiving and unarchiving just as competently, and doesn't bother with the nag screens. What's more, the .7z format, which uses AES-256 encryption and a super-high compression ratio, is both smaller and, usually, faster than using .ZIP or .RAR to squash down your files.
www.7-zip.org

Office suites

39 GOOGLE DOCS

Although it's missing many of the more advanced features of full office suites, those are generally things you shouldn't be using an office package for anyway. Google Docs—and Sheets, and Slides—rocks a winning combination of solid core features, constant accessibility, integration with online storage, and companion mobile apps, which (awkwardly) offer you the same functionality on your phone. You can import and export in any format you choose—what's not to like?
http://docs.google.com

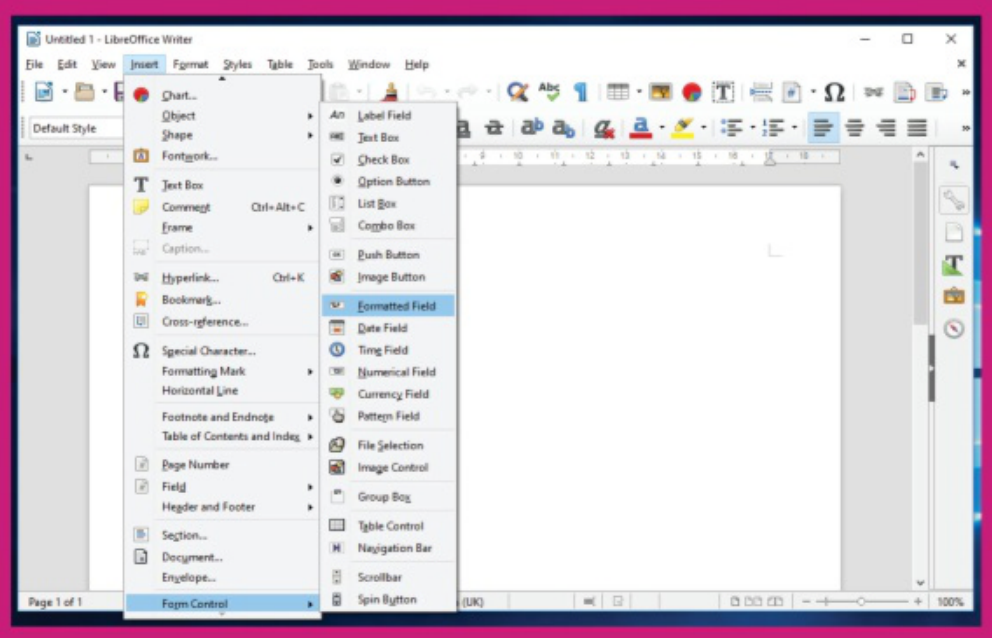
38 APACHE OPENOFFICE

One of many successors of original Microsoft Office alternative StarOffice, OpenOffice (passed on to Apache after previous owner, Oracle, abandoned the project) contains a complete suite of software, ranging from the core word processor/spreadsheet/presentations triumvirate to software specifically designed for vector drawing, laying out mathematical formulae, and a database. If you're not shelling out for Microsoft's suite, this'll get the job done.
www.openoffice.org

39 LIBREOFFICE

LibreOffice is, somewhat naturally, just like OpenOffice—while the two packages have followed different development lines since mid-2013, they're based on the same code, and retain the same naming convention (and, in most cases, a very similar interface) for their central six apps. It's up to you which free office branch you follow; ignoring the frequent squabbling that split the two (and fellow StarOffice fork NeoOffice), they're just as capable as one another.
www.libreoffice.org PC

▼ Who knew that the world of free office software was so rife with drama and conflict?!



PLAY WINDOWS GAMES IN LINUX

Discover how to get classic Windows games working in Ubuntu with Nick Peers.

Game developers are increasingly taking advantage of the growing market in Linux gaming, but that's not always been the case, and even now some games aren't released outside of Windows. Thanks to a clever tool called Wine, though, you can run many Windows games—and other apps, including Office—as though they were native to Linux.

Wine provides a skeletal virtual version of Windows, inside which you install extra components and perform various tweaks (for example, selecting which version of Windows you want to emulate) to get your app working. Sadly, it's not a silver bullet that will get all your Windows games working in Linux, but it should be able to give you access to at least some of them.

The biggest hurdle is that Wine is a command-line tool—great for purists; not so convenient if you want to point and click your way to gaming heaven. Thankfully, others have developed graphical "wrappers" that sit on top of Wine to make it easier to use from the Ubuntu desktop.

In this guide, we're focusing on one such free tool called PlayOnLinux. Not only does it provide a graphical front end, but PlayOnLinux (or POL to its pals) provides a series of pre-built scripts that, in theory, make it easy to install and play specific games. As you'll see, in practice that's not always the case, but we'll take you on a tour of the program's features, plus step you through the process of installing both through scripts and manually, to hopefully get your game up and running.

We'll also explore an alternative Wine wrapper (and touch on another way to play Windows games in Linux), plus reveal how to play old DOS games in addition to Windows classics. So, plug in your game controller, dig out your old Windows discs, and prepare to enter gaming nirvana.

acer

For the most part, playing Windows games in Linux involves the Wine emulator. PlayOnLinux (POL) is effectively a more user-friendly front end to Wine, enabling you to configure and access it from outside the command line. Generally, Windows games are played in a 32-bit environment, so if you're running a 64-bit build of Linux, you need to open a Terminal window, and then issue the following commands:

```
$ sudo dpkg --add-architecture i386
$ sudo apt-get update
```

The following steps install the latest version of Wine:

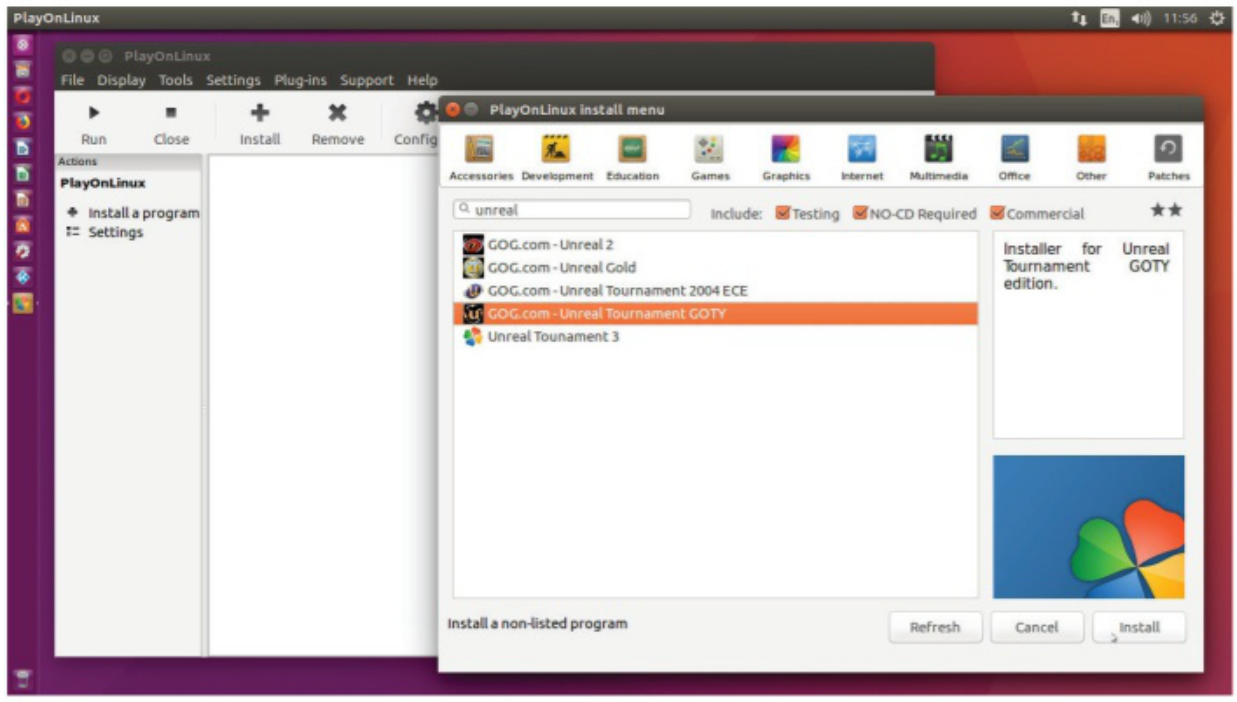
```
$ wget -nc https://dl.winehq.org/wine-builds/Release.key
$ sudo apt-key add Release.key
$ sudo apt-add-repository https://dl.winehq.org/wine-builds/ubuntu/
$ sudo apt-get update && sudo apt-get install --install-recommends winehq-stable
```

Note: This is a hefty install—around 800MB—so make sure you have sufficient drive space. Once done, you can move on to install POL itself:

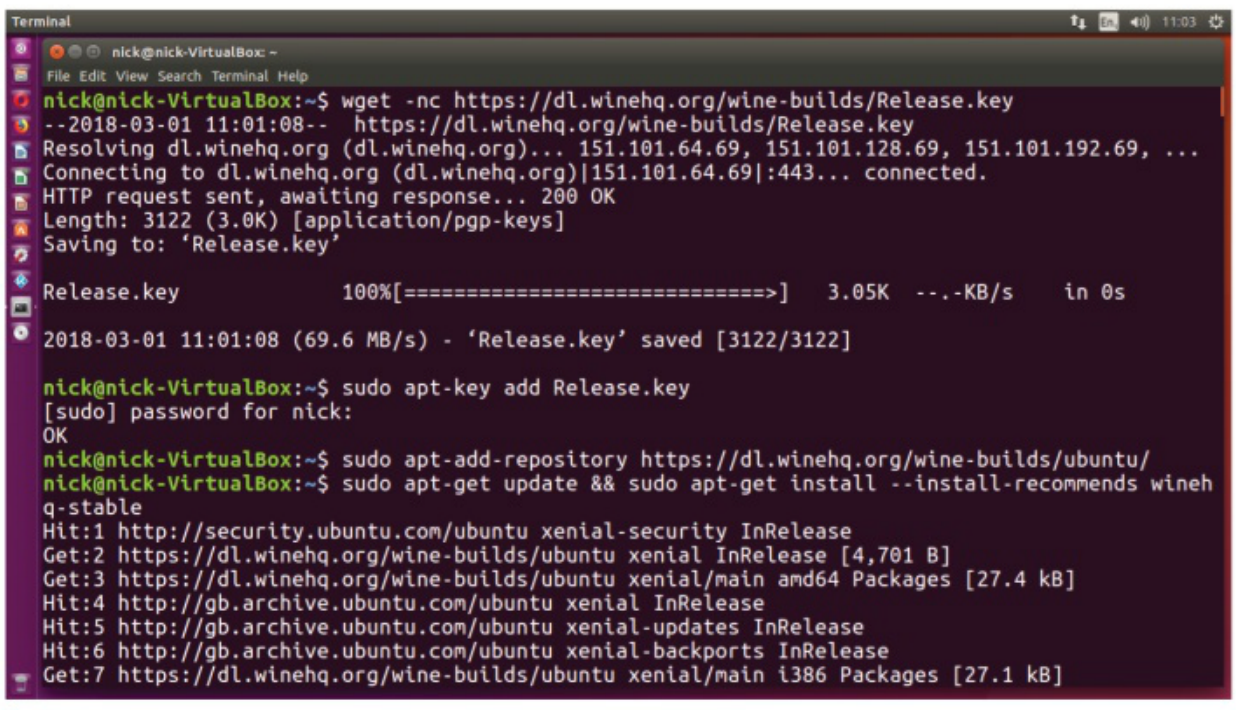
```
$ wget -q "http://deb.playonlinux.com/public.gpg" -O- | sudo apt-key add -
$ sudo wget http://deb.playonlinux.com/playonlinux_trusty.list -O /etc/apt/sources.list.d/playonlinux.list
$ sudo apt-get update && sudo apt-get install playonlinux
```

Open Launcher and type "PlayOnLinux" to launch the app. When prompted, we recommend clicking "Yes" to anonymously record and share your hardware configuration with POL the first time you attempt to run a Windows program—this helps determine its suitability for similar setups as yours.

The main screen appears, and you might be immediately informed that a newer version is available—if this is the case, go to **www.playonlinux.com/en/download.html** and save the latest deb file (4.2.12) to your "Downloads" folder, then open a Terminal window, and type the following to install it:



▲ **POL provides literally hundreds of scripts for games.**


Terminal
nick@nick-VirtualBox: ~
File Edit View Search Terminal Help
nick@nick-VirtualBox:~$ wget -nc https://dl.winehq.org/wine-builds/Release.key
--2018-03-01 11:01:08-- https://dl.winehq.org/wine-builds/Release.key
Resolving dl.winehq.org (dl.winehq.org)... 151.101.64.69, 151.101.128.69, 151.101.192.69, ...
Connecting to dl.winehq.org (dl.winehq.org)|151.101.64.69|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 3122 (3.0K) [application/pgp-keys]
Saving to: 'Release.key'
Release.key 100%[=>] 3.05K --.-KB/s in 0s
2018-03-01 11:01:08 (69.6 MB/s) - 'Release.key' saved [3122/3122]
nick@nick-VirtualBox:~$ sudo apt-key add Release.key
[sudo] password for nick:
OK
nick@nick-VirtualBox:~$ sudo apt-add-repository https://dl.winehq.org/wine-builds/ubuntu/
nick@nick-VirtualBox:~$ sudo apt-get update && sudo apt-get install --install-recommends winehq-stable
Hit:1 http://security.ubuntu.com/ubuntu xenial-security InRelease
Get:2 https://dl.winehq.org/wine-builds/ubuntu xenial InRelease [4,701 B]
Get:3 https://dl.winehq.org/wine-builds/ubuntu xenial/main amd64 Packages [27.4 kB]
Hit:4 http://gb.archive.ubuntu.com/ubuntu xenial InRelease
Hit:5 http://gb.archive.ubuntu.com/ubuntu xenial-updates InRelease
Hit:6 http://gb.archive.ubuntu.com/ubuntu xenial-backports InRelease
Get:7 https://dl.winehq.org/wine-builds/ubuntu xenial/main i386 Packages [27.1 kB]

▲ **You only need the command line to install Wine and PlayOnLinux.**

```
$ sudo apt install ~/Downloads/PlayOnLinux_4.2.12.deb
$ playonlinux --version
```

This should now read "4.2.12." Launch PlayOnLinux again.

INSTALL A SUPPORTED GAME

When the main screen appears again, click "Install a program," and the "Install" menu appears. Click the "Games" button to see a list of supported games. Either browse through the list or use the "Search" button to find a specific game. Some of the games listed require the original disc to run, so make sure that's handy if required.

If you find the game you want, click "Install," and note the warning: Games should always be installed to "drive C" of the virtual machine; don't automatically launch the game at the end of the installation if asked; and only reboot virtual Windows if asked to by the program. Click "Next."

You're also told how POL isn't related to WineHQ—one additional advantage of POL is that it allows you to install and run multiple versions of Wine at the same time, so if an earlier version is known to work with a specific game, the POL script installs that, and uses it automatically. This warning merely points out you should address any problems you encounter to the POL website, not WineHQ. Click "Next" again.

The installation wizard proper launches—work your way through it as you would with any other Windows program. Step one may be to download a specific version of Wine (and required prerequisites) known to work with the game you've chosen—this is done automatically for you.

Next, you might be prompted to choose the game source. This could be a setup file you've downloaded manually to your PC, a program download (which POL handles for you), a Steam store version (in which case, a virtual version of Steam needs to be installed), or the original game CD.

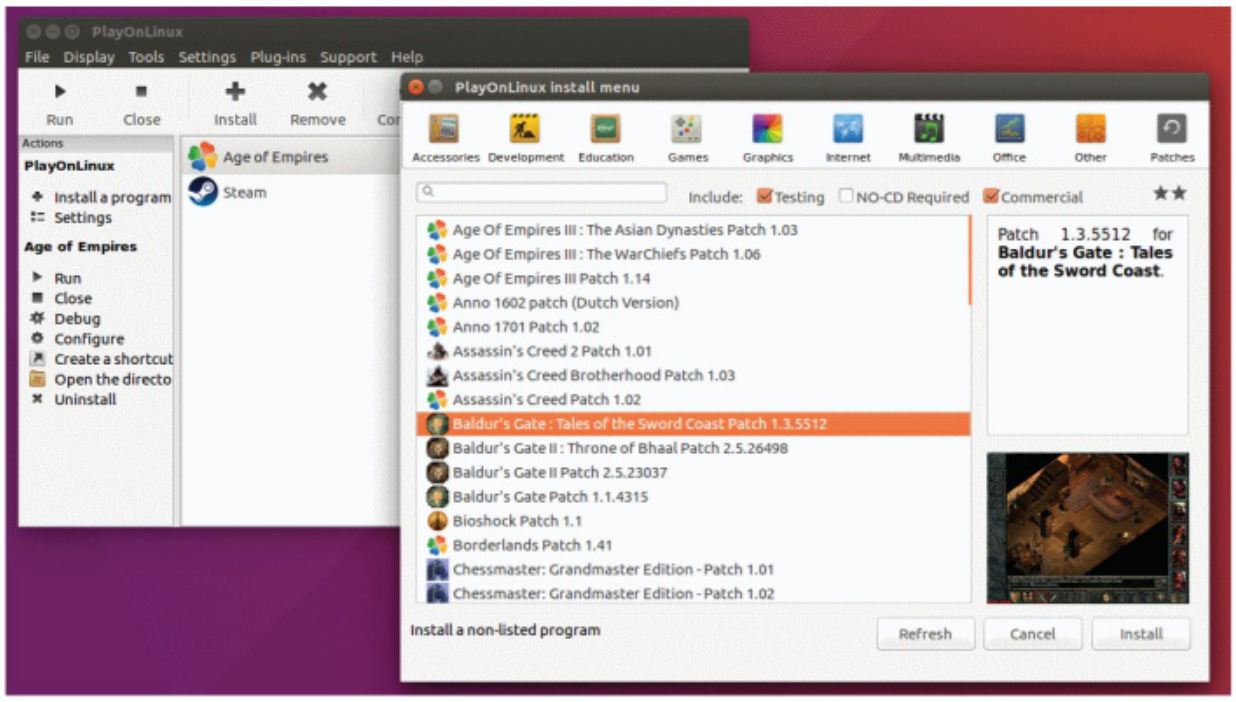
Any known additional prerequisites—such as Microsoft fonts—are now flagged up, and again installed automatically for you. This is where the automatic wizard comes into its own, highlighting settings and Windows elements you may not be aware of. You might also be asked additional questions, such as how much memory your graphics card has; enter the following in a Terminal window if you're not sure.

```
sudo dmseg | grep drm
```

If the script continues to run properly, skip to "Install the game" ahead.

FIND AN UNSUPPORTED GAME

If you can't find your game listed in PlayOnLinux—or the script fails to work (see the box opposite for a workaround involving Steam-powered games)—don't panic (yet). Head to the Wine Application Database at **https://appdb.winehq.org** and type the name of your game into the Search box. Scroll down, and click the first AppDB result. Note the game's rating: Platinum and Gold indicate the game should work with few problems; Silver and Bronze suggest there may be issues, such as random crashes; Garbage means it won't work. If multiple versions are listed, choose the one


PlayOnLinux
File Display Tools Settings Plug-ins Support Help
Run Close Install Remove
Actions
PlayOnLinux
Install a program
Settings
Age of Empires
Run
Close
Debug
Configure
Create a shortcut
Open the directo
Uninstall
Age of Empires
Steam
PlayOnLinux install menu
Accessories Development Education Games Graphics Internet Multimedia Office Other Patches
Include: Testing NO-CD Required Commercial
Age Of Empires III : The Asian Dynasties Patch 1.03
Age Of Empires III : The WarChiefs Patch 1.06
Age Of Empires III Patch 1.14
Anno 1602 patch (Dutch Version)
Anno 1701 Patch 1.02
Assassin's Creed 2 Patch 1.01
Assassin's Creed Brotherhood Patch 1.03
Assassin's Creed Patch 1.02
Baldur's Gate : Tales of the Sword Coast Patch 1.3.5512
Baldur's Gate II : Throne of Bhaal Patch 2.5.26498
Baldur's Gate II Patch 2.5.23037
Baldur's Gate Patch 1.1.4315
Bioshock Patch 1.1
Borderlands Patch 1.41
Chessmaster: Grandmaster Edition - Patch 1.01
Chessmaster: Grandmaster Edition - Patch 1.02
Patch 1.3.5512 for Baldur's Gate : Tales of the Sword Coast.
Install a non-listed program
Refresh
Cancel
Install

▲ **Check for patches after installing your games.**

closest to your distro and the game.

From here, work through the "Test Results" and "Known Bugs" to see how other people have fared, then expand "HowTo/Notes" to see what guidance there is in terms of prerequisites, which version of Wine to choose, and so on. Also check "Comments" for further information.

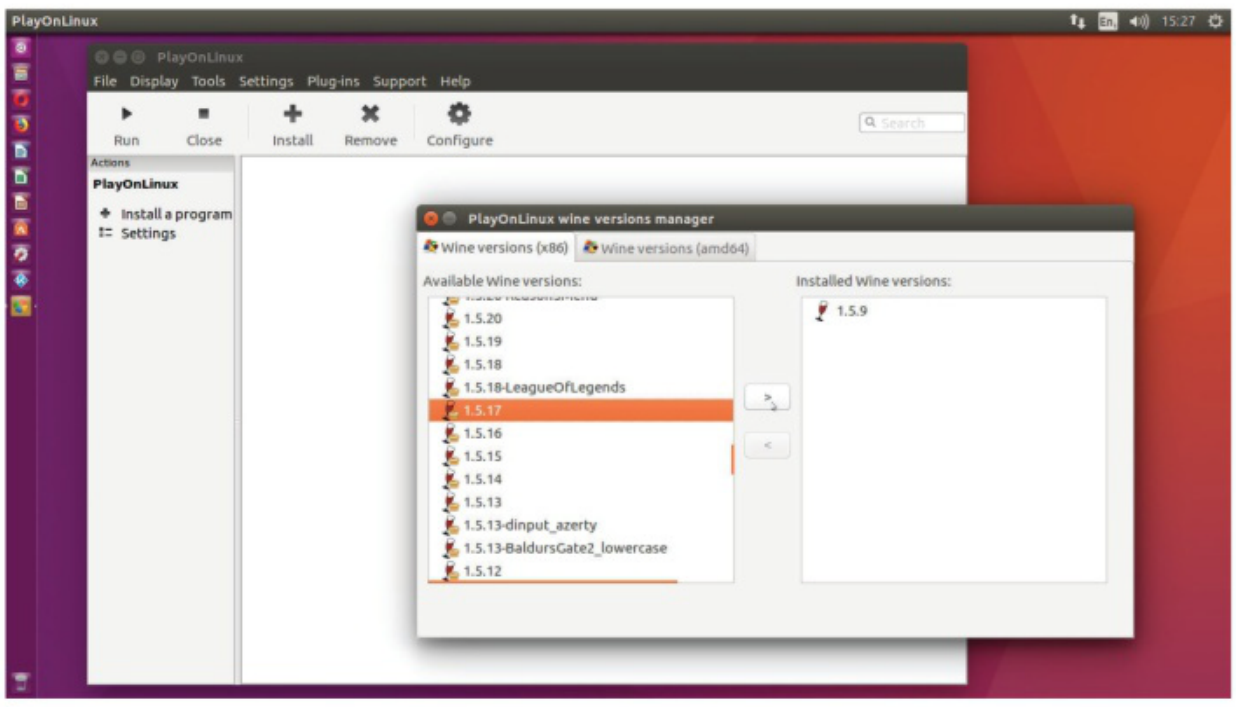
In some cases, you receive detailed instructions on what extras to install and how to configure your virtual disk, but sometimes the notes are incredibly sketchy. Try Googling the name of your game along with "Wine" or "PlayOnLinux" to see if you can find any more information—typically via forum posts from people asking the exact same questions you are.

If you're happy there's a good chance the game will work, first make sure you have the correct version of Wine installed (you can install multiple versions). In PlayOnLinux, open the "Tools" menu, and select "Manage Wine Versions." You'll see a list of available Wine versions on the left under the "Wine versions (x86)" tab. Scroll through, finding the one recommended, and click the ">" button to install it.

Close the versions manager window, then click "Install a program," followed by "Install a non-listed program." Click "Next," then choose "Install a program in a new virtual drive," and click "Next" again. Give a name for your game's virtual drive—the game's name should suffice. You're given three optional choices to select: Choose a different version of Wine; configure Wine; and install some libraries. Select those you'll need—"Use another version of Wine" almost certainly—then click "Next." If you're choosing a different version of Wine, select it from the list. Click "Next." Leave "32-bit Windows installation" selected, and click "Next" again.

If you opted to install additional libraries, you're given a list of options marked with a "POL_" prefix. They're largely self-explanatory—you'll see many refer to installing additional components, such as DirectX or GDIplus, for example.

If you opt to tweak Wine settings, the Wine configuration window opens. This is split into seven tabs, all of which are largely self-explanatory. Key ones to consider



▲ **POL enables you to run multiple versions of Wine at once.**

INSTALL STEAM IN POL

PlayOnLinux's scripts aren't always capable of getting the job done, sadly. There's a particular issue with Steam-powered games, where the installer falls over attempting to insert Steam into the virtual drive you've created. The solution here is to install Steam directly first, using the POL script—after it's successfully installed, double-click the icon, and allow it to update itself. If you receive an error saying it's crashed, but a progress bar is still running, leave it to finish updating, then click "Next" to remove the crash window, and log in to your Steam account.

As things stand, Steam works, but is unable to access the store in Ubuntu 16.04 LTS. To resolve this, first select its shortcut in the main POL window, and then click "Configure." Type the following into the "Arguments" box on the "General" tab.

```
-no-cef-sandbox
```

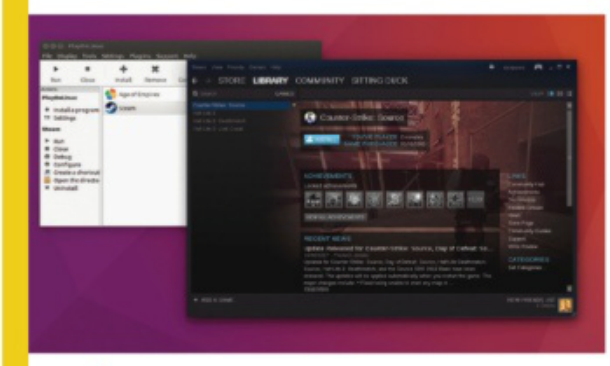
(This constitutes a security risk, just so you know.) Now switch to the "Install Components" tab, and install the following elements: d3dx9_42, vcrun2008, and xact. You also need to install vcrun2015, but it's not present. Instead, switch to the "Miscellaneous" tab, and click "Open a shell." Now type the following commands into the shell:

```
$ wget https://raw.githubusercontent.
com/Winetricks/winetricks/master/src/
winetricks
$chmod +x winetricks
```

With the following command, substitute "username" with your own username:

```
$ WINEPREFIX=/home/username/.
PlayOnLinux/wineprefix/Steam ./
winetricks -q vcrun2015
```

After running, it appears to throw up an error. No matter—close the window, and relaunch Steam. After downloading another update, you'll finally have access, enabling you to download and try to run any games you've purchased.



▲ **Play Windows Steam games with POL.**

PLAY DOS GAMES

Ever wanted to revisit classic games from the '90s? DOSBox enables you to play games written for MS-DOS, and while it's possible to tie it into PlayOnLinux, it's far simpler to just install it natively:

```
$ sudo apt-get install dosbox
$ mkdir -p ~/dos/c
```

DOS games reside in their own folder, and you can source a wide variety from www.abandonia.com. Download a game in Zip format to your Downloads folder, then extract its contents into the dos/c folder you created in your Home folder.

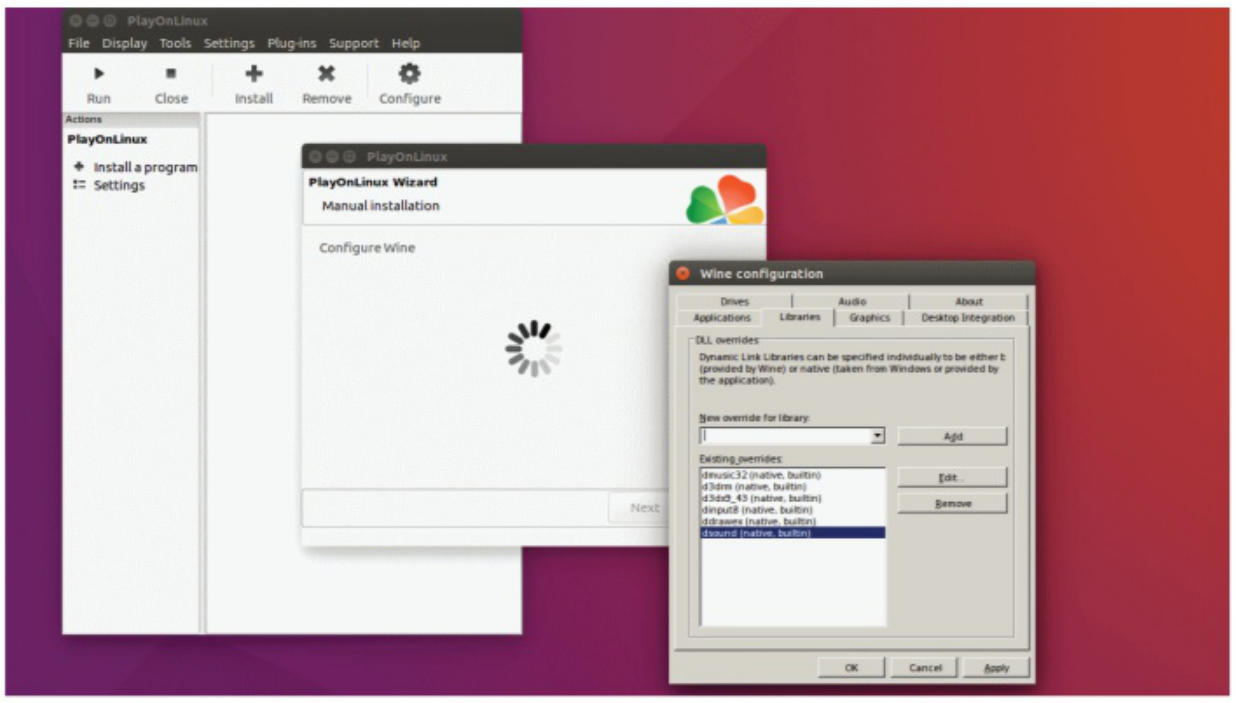
Now type "dosbox" and hit Enter to launch DOSBox in its own window. Next, enter the following command for it to mount your /dos/c folder as its own C drive:

```
$ mount c /home/username/dos/c
$ c:
```

Type "dir" and hit Enter to verify you're in the correct spot—you'll see folders for each of the games you want to run. Type "cd dirname" (for example, "cd civ1" for Civilization) to switch directory to the folder, then type "dir" again to identify the game file itself ("civ" in the case of our Civilization example). Finally, type the file name, and hit Enter to launch—and play—the game.

If prompted, choose "VGA (256 colors)" for graphics, and "SoundBlaster" for sound. DOSBox should also work with any basic USB controller recognised by Linux, as well as your mouse and keyboard. When you click inside the DOSBox window, your mouse will be captured permanently—press Ctrl-F10 to release the mouse back to the main desktop, and visit **www.dosbox.com** for a full guide to playing DOS games on your PC.

▲ **Revisit the '90s with DOSBox.**



▲ **Configure your virtual desktop using the Wine configuration dialog box.**

are "Libraries," where you can specify DLL overrides for compatibility purposes; "Graphics," for determining whether the program runs full-screen or in its own desktop window; and "Audio," for tweaking sound settings, should you need to. Click "OK" when done.

INSTALL THE GAME

Whether you're installing from a script or manually, the actual game setup process is the same. Hopefully, your CD or DVD will be automatically detected, otherwise click the "Browse" button to locate your game's setup file—if it's on CD or DVD, select the disc in the "Places" menu. Locate the file you need to run—try setup.exe if there's no guidance from the AppDB—and click "Open," then "Next." PlayOnLinux now tries to install the game.

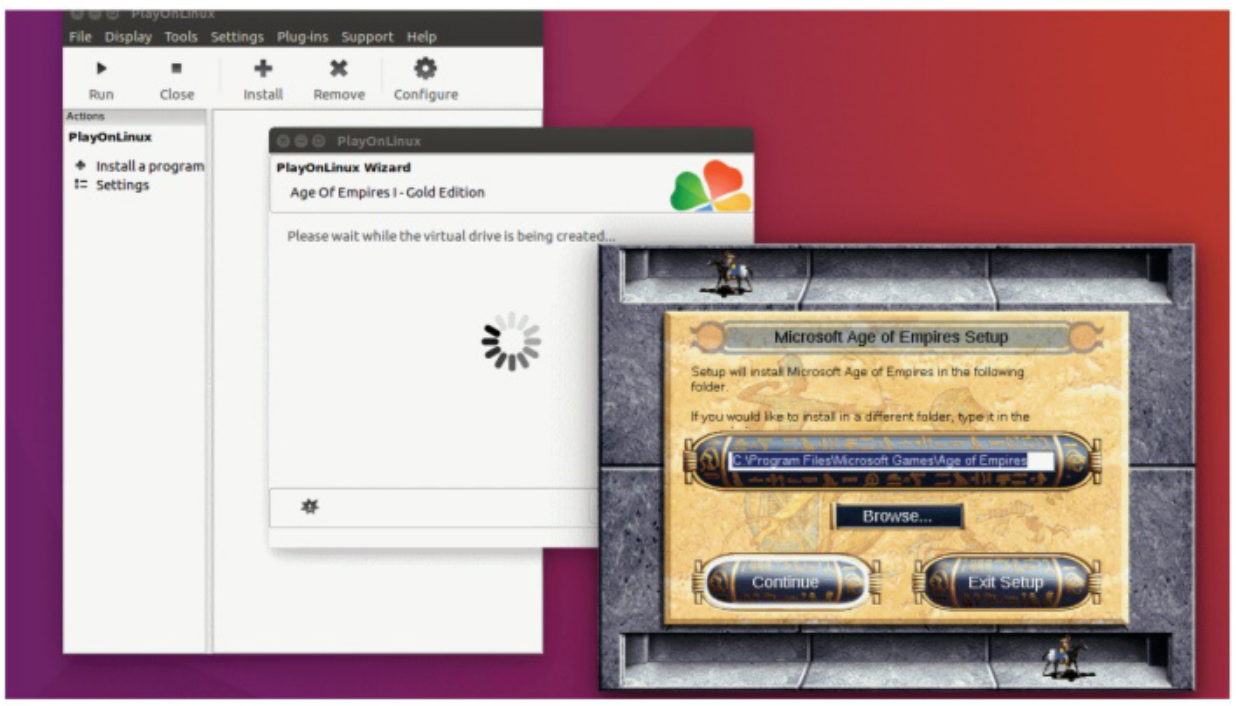
You should see a setup screen from the program itself, which is actually running inside the virtual drive POL created—in other words, proof your skeletal version of Windows is up and running. From here, it's a case of following the game's own wizard through to see whether it's able to complete successfully—leave the default file location selected when prompted. If errors are thrown up, you may find the game still runs, so attempt to continue to the end if possible by clicking "Next."

If successful, you're prompted to choose a file that PlayOnLinux will use as a shortcut—select it from the list, or click "Browse" if none is provided to hunt your virtual drive for one. It uses the Windows filesystem, so start your search under C:\Program Files. Once done, you're prompted to add as many additional shortcuts as you need. Leave "I don't want to make another shortcut" selected, and click "Next" when you're done.

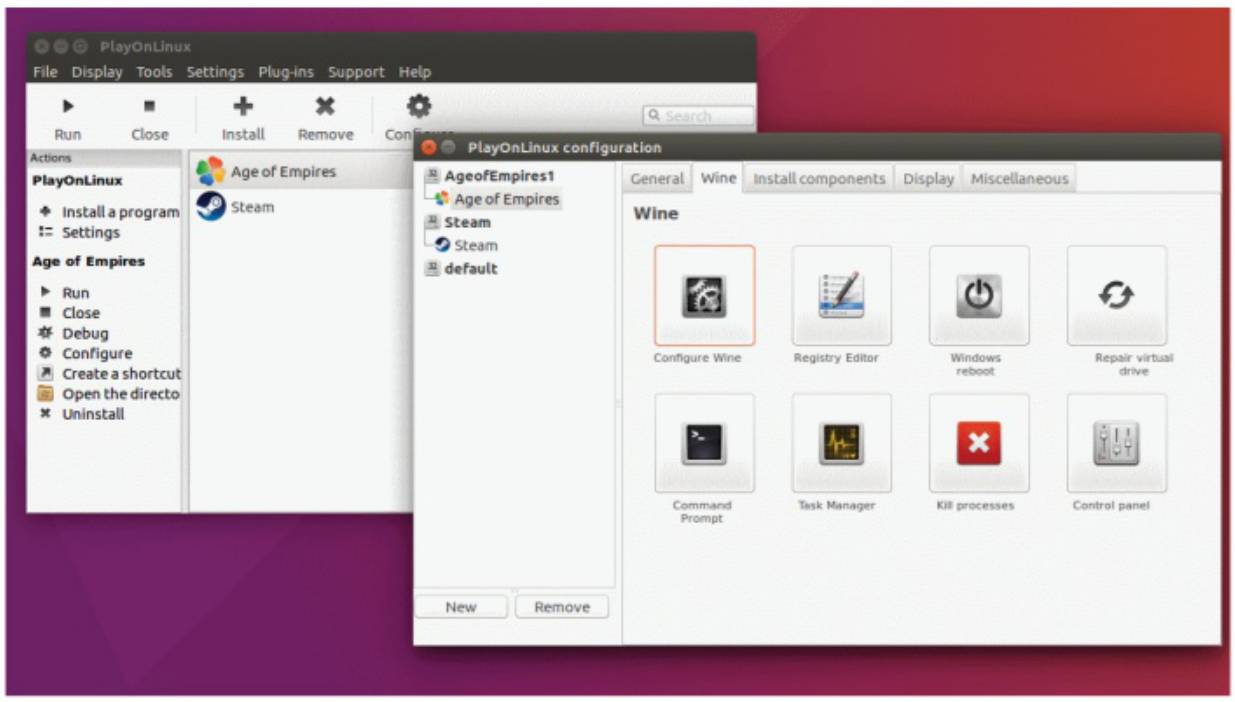
These shortcuts appear on both your desktop and the main PlayOnLinux window; the former enables you to launch your game without having to open PlayOnLinux first, but can be safely deleted without removing the others. You can recreate desktop shortcuts from the main PlayOnLinux window by selecting a shortcut and clicking "Create a shortcut" in the left-hand pane.

THE MOMENT OF TRUTH

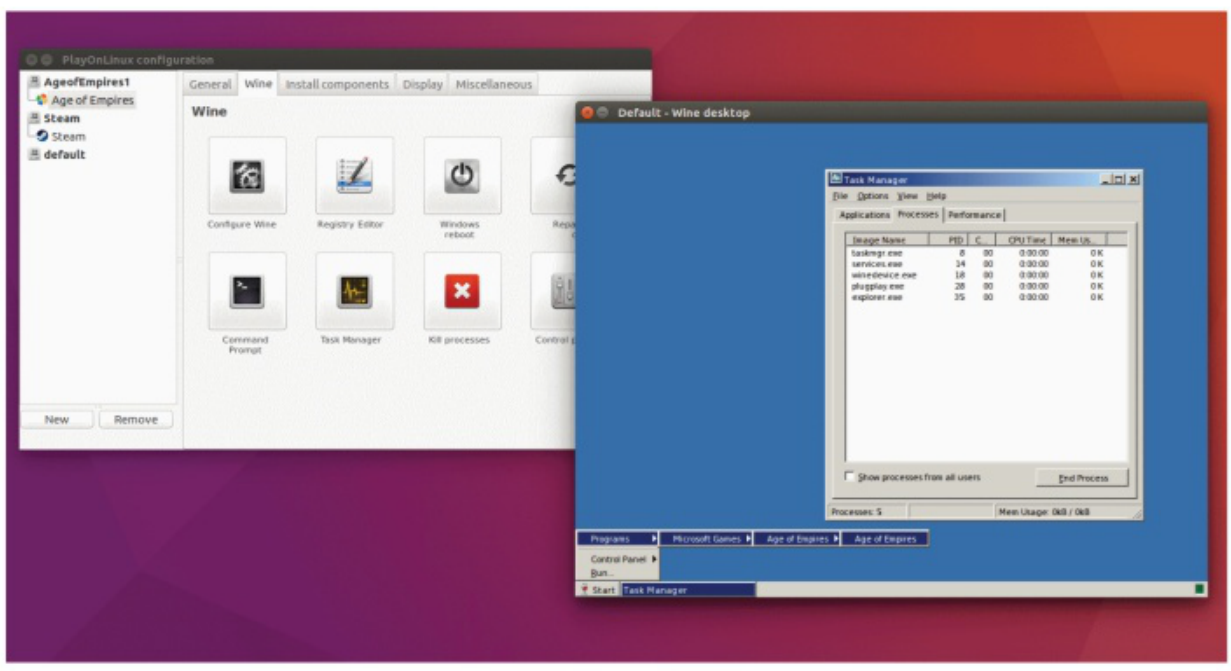
It's time to see how your game plays—if you've


File Display Tools Settings Plug-ins Support Help
Run Close Install Remove Configure
Actions
PlayOnLinux
Install a program
Settings
PlayOnLinux
PlayOnLinux Wizard
Age Of Empires I - Gold Edition
Please wait while the virtual drive is being created...
Microsoft Age of Empires Setup
Setup will install Microsoft Age of Empires in the following folder.
If you would like to install in a different folder, type it in the
C:\Program Files\Microsoft Games\Age of Empires
Browse...
Continue
Exit Setup

▲ **Games are installed just as they would be in Windows.**



▲ **You can tweak your virtual desktop via a series of tabs.**



▲ **Run games inside their own virtual desktop window if necessary.**

installed it manually using a guide from AppDB, you should have forewarning about any potential issues, but your experience may be different. Double-click the shortcut, which should launch the game directly or open Wine Explorer (in which case, click the shortcut again). The game will hopefully launch, and you can start playing it. In most cases, however—and particularly if you've installed it manually—things won't be quite that simple, in which case, you may need to dig deeper into your virtual drive's configuration.

First, the game may change your desktop resolution to 640x480, and not reset after it's finished (or crash, leaving you stuck with only the top-left corner of your screen showing). To restore your original desktop resolution, press Ctrl-Alt-T to open a Terminal window, then type the following, and hit Enter:

```
$ xrandr -s 0
```

The screen blanks momentarily, and your default resolution is restored. To prevent this happening again, try running the game in a virtual window: Click "Configure," select your virtual drive, and switch to the "Wine" tab. Click "Configure Wine," and wait for the Windows-like multi-tabbed window to appear. Switch to the "Graphics" tab, and select "Emulate a virtual desktop," then set it to the game's resolution: 640x480, 800x600, or 1024x768 in most cases, depending on the game's age.

The POL configuration window also offers more configuration options—the "Wine" tab gives you access to your virtual drive's Task Manager, Control Panel, and a Kill Processes option, if you're having trouble shutting it down, for example. Return to the "General" tab to run arguments when launching your game. The "Install components" tab enables you to install more Windows components if necessary, while "Display" enables you to experiment with various settings that may or may not fix display glitches. Finally, "Miscellaneous" lets you open a shell to your virtual drive or manually launch a Windows .exe file (a setup file, for example, not covered under "Install components").

As before, these features are quite technical and you're best served by investigating the POL forums and other web resources for help in understanding and using these with specific programs. And if that's too technical, check out the box on the right for an alternative to PlayOnLinux that may not be free, but is simpler to use, better supported, and provides working scripts for a greater number of games.

OTHER LINUX GAMING OPTIONS

PlayOnLinux isn't the only way to (try to) run Windows software in Linux. As we've seen, POL is basically a user-friendly wrapper for Wine, and while it makes things easier—particularly in the way it supports multiple Wine versions for compatibility purposes—it's not perfect. As you've seen from the main feature, you'll often be forced to bypass its scripts and attempt to wrestle with its controls—in a more user-friendly interface than offered by Wine itself, though—to try to get your game running.

If the idea of Wine appeals, but spending hours trying to get your game working doesn't, take a look at CrossOver Linux (**www.codeweavers.com**). Like POL, it's a wrapper for Wine, but it's better developed, because while it's not free, you're paying to support Wine development, and many improvements in Wine have come about through the work of CrossOver's devs.

A trial version is available, giving you ample time to discover whether you'll have more success installing and running your game through CrossOver as opposed to POL—we got Thief 2 and Unreal Tournament GOTY running in CrossOver, for example. The full version can be purchased for $39.95 as a one-off cost, or you can pay $59.95 for 12 months' updates and personal support, to help you try to get your games to run.

Another workaround can be tried if you have access to a Windows license: Install a virtual Windows machine using VirtualBox (**www.virtualbox.org**), then install your game in that. Be sure to give it two cores if you can, as well as plenty of RAM—also max out the graphics RAM, and select both 2D and 3D support to give it the best chance of providing reasonable performance for your game.

▲ **CrossOver Linux works in a similar way to POL.**

SPEED UP WINDOWS

Give your PC a burst of speed with this collection of tools to tweak, optimise, and reinstall Windows.

When it comes to outright speed, your PC never seems to have enough. Or to put it another way, it doesn't matter how smoothly it's running, your PC could always do with being that bit faster. Armed with the right know-how, you can fine-tune your PC to squeeze more performance from it, but the effort involved can be more than it's worth.

Which is where we come in. In this feature, we've dug out the finest free tools we know of that can help speed up your machine. We kick things off by revealing our favorite tools for fine-tuning your system. Your hardware could use some optimization, too, so we've collected the best overclocking and tuning apps for pushing it beyond its limits. And finally, when you next bite the bullet and reinstall Windows, we reveal five tools that can help safeguard and speed up the process, before running you through the steps you need to take to restore Windows to its pristine, like-new form, unencumbered by bloated apps and collected detritus.

Your computer is ready to take its performance to the next level with the help of our essential apps, so turn the page to get started with giving it a much-needed boost of speed.

> "We kick things off by revealing our favorite tools for fine-tuning your system."

Tune up your system

Discover how to streamline your PC for an extra burst of speed with the help of these powerful—and free—apps.

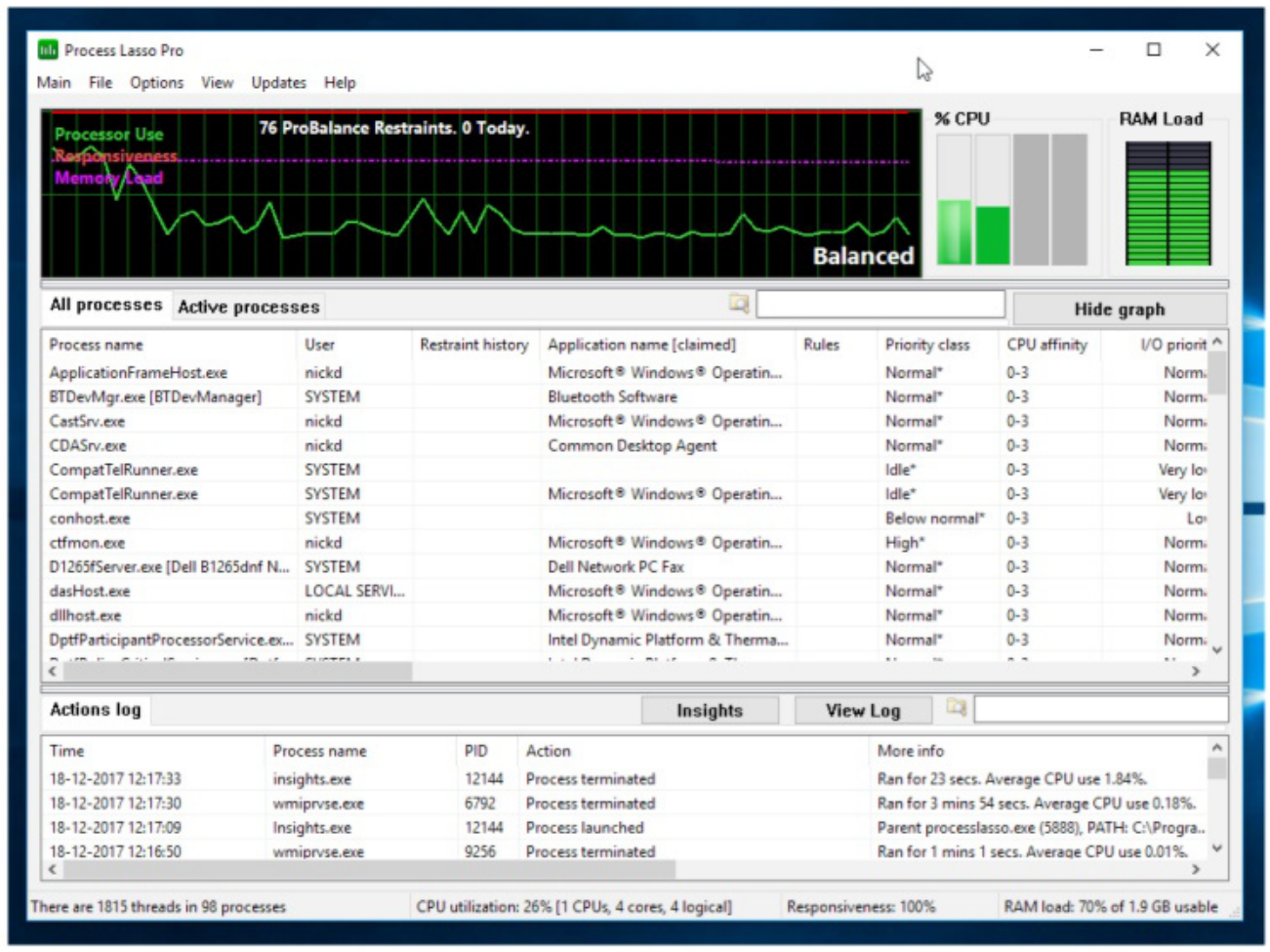
Windows has been designed for maximum compatibility, so while it runs on a wide range of PCs, it's not been optimised for any of them. This is where the apps in this part of the feature come into play. They give you the tools required to speed up your PC in several ways. As is usually the case with apps, less is more—there's no point recommending 100 apps whose combined demands outweigh the benefits of using them in the first place, which is why we've pared them down to five.

You'll find our favorite tool for managing startup, enabling you to both monitor and improve the way Windows loads. If you're frequently blighted by lockups, then Process Lasso can keep those runaway programs in check. There's also a safe tool for tweaking low-level Services to free up more system resources, JetBoost for temporarily halting unnecessary processes when running games or other demanding applications, and a handy defrag tool to build upon Windows' own.

PROCESS LASSO

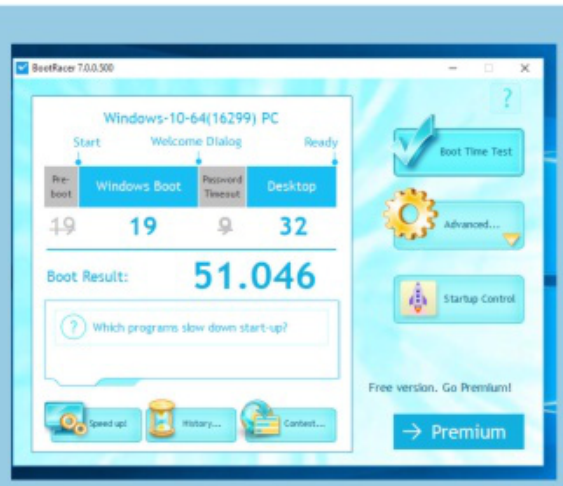
If your machine frequently appears to stop responding or grinds to a halt momentarily, the culprit is usually a program or system process that's making excessive demands on your system to the detriment of the other running programs and processes, including Windows itself.

This problem is more acute on older or lower-powered PCs with 2GB of RAM or less, where there's less memory to go around. Process Lasso (**https://bitsum.com**) monitors your PC's processes, and when it detects one making runaway demands, it temporarily lowers its priority, to ensure your PC keeps running smoothly. The free version includes all the core functionality, or upgrade for more features: A lifetime single-user license for the Pro version costs $36; Home Pro ($46) covers every PC in your home.


Process Lasso Pro
Main File Options View Updates Help
Processor Use
Responsiveness
Memory Load
76 ProBalance Restraints. 0 Today.
Balanced
% CPU
RAM Load
All processes
Active processes
Hide graph
Process name | User | Restraint history | Application name [claimed] | Rules | Priority class | CPU affinity | I/O priorit
ApplicationFrameHost.exe | nickd | Microsoft® Windows® Operatin... | Normal* | 0-3 | Norm
BTDevMgr.exe [BTDevManager] | SYSTEM | Bluetooth Software | Normal* | 0-3 | Norm
CastSrv.exe | nickd | Microsoft® Windows® Operatin... | Normal* | 0-3 | Norm
CDASrv.exe | nickd | Common Desktop Agent | Normal* | 0-3 | Norm
CompatTelRunner.exe | SYSTEM | | Idle* | 0-3 | Very lo
CompatTelRunner.exe | SYSTEM | Microsoft® Windows® Operatin... | Idle* | 0-3 | Very lo
conhost.exe | SYSTEM | | Below normal* | 0-3 | Lo
ctfmon.exe | nickd | Microsoft® Windows® Operatin... | High* | 0-3 | Norm
D1265fServer.exe [Dell B1265dnf N... | SYSTEM | Dell Network PC Fax | Normal* | 0-3 | Norm
dasHost.exe | LOCAL SERVI... | Microsoft® Windows® Operatin... | Normal* | 0-3 | Norm
dllhost.exe | nickd | Microsoft® Windows® Operatin... | Normal* | 0-3 | Norm
DptfParticipantProcessorService.ex... | SYSTEM | Intel Dynamic Platform & Therma... | Normal* | 0-3 | Norm
Actions log
Insights
View Log
Time | Process name | PID | Action | More info
18-12-2017 12:17:33 | insights.exe | 12144 | Process terminated | Ran for 23 secs. Average CPU use 1.84%.
18-12-2017 12:17:30 | wmiprvse.exe | 6792 | Process terminated | Ran for 3 mins 54 secs. Average CPU use 0.18%.
18-12-2017 12:17:09 | Insights.exe | 12144 | Process launched | Parent processlasso.exe (5888), PATH: C:\Progra..
18-12-2017 12:16:50 | wmiprvse.exe | 9256 | Process terminated | Ran for 1 mins 1 secs. Average CPU use 0.01%.
There are 1815 threads in 98 processes
CPU utilization: 26% [1 CPUs, 4 cores, 4 logical]
Responsiveness: 100%
RAM load: 70% of 1.9 GB usable

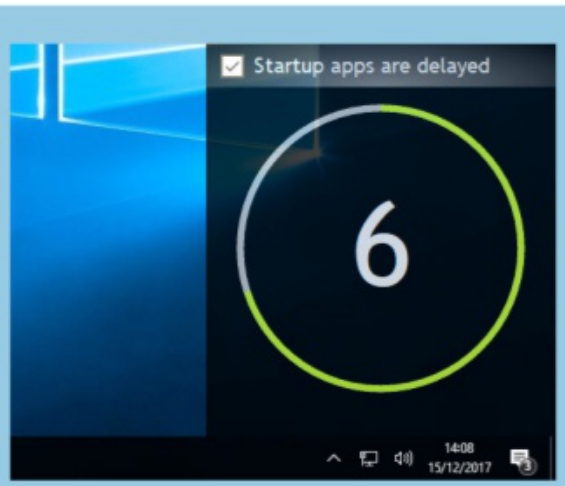
MONITOR AND IMPROVE WINDOWS STARTUP

BootRacer (**www.greatis.com/bootracer**) has become our go-to app for managing startup. Not only does it enable you to see which programs are launching with Windows, but it times everything, too, enabling you to keep an eye on the boot process, and giving you a heads-up should some resource-sapping program suddenly insert itself into the startup process. Here's a quick rundown of its key features.



1 TIME YOUR START

The first thing BootRacer does is measure your start time, from the moment your PC is switched on until your startup apps finish loading. This helps you identify bottlenecks at different points of the process, so you can target your troubleshooting.



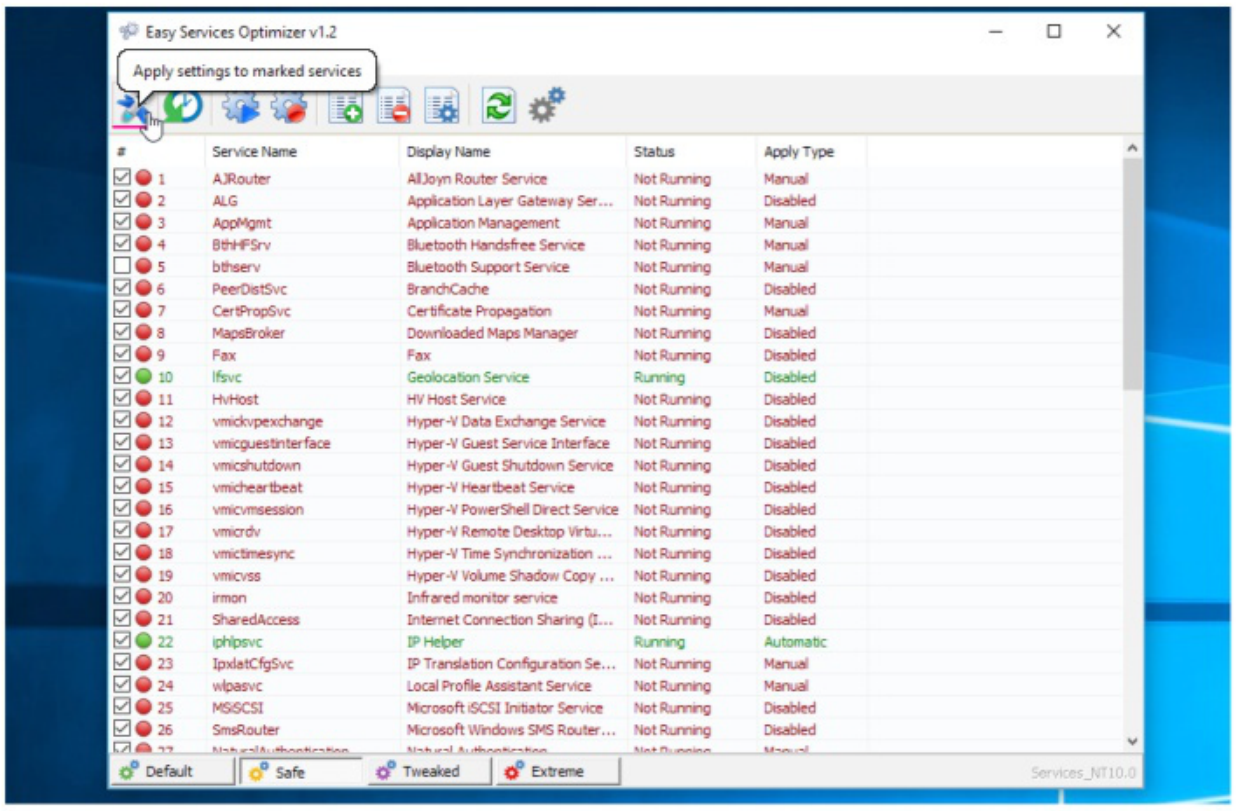
2 DELAYED START

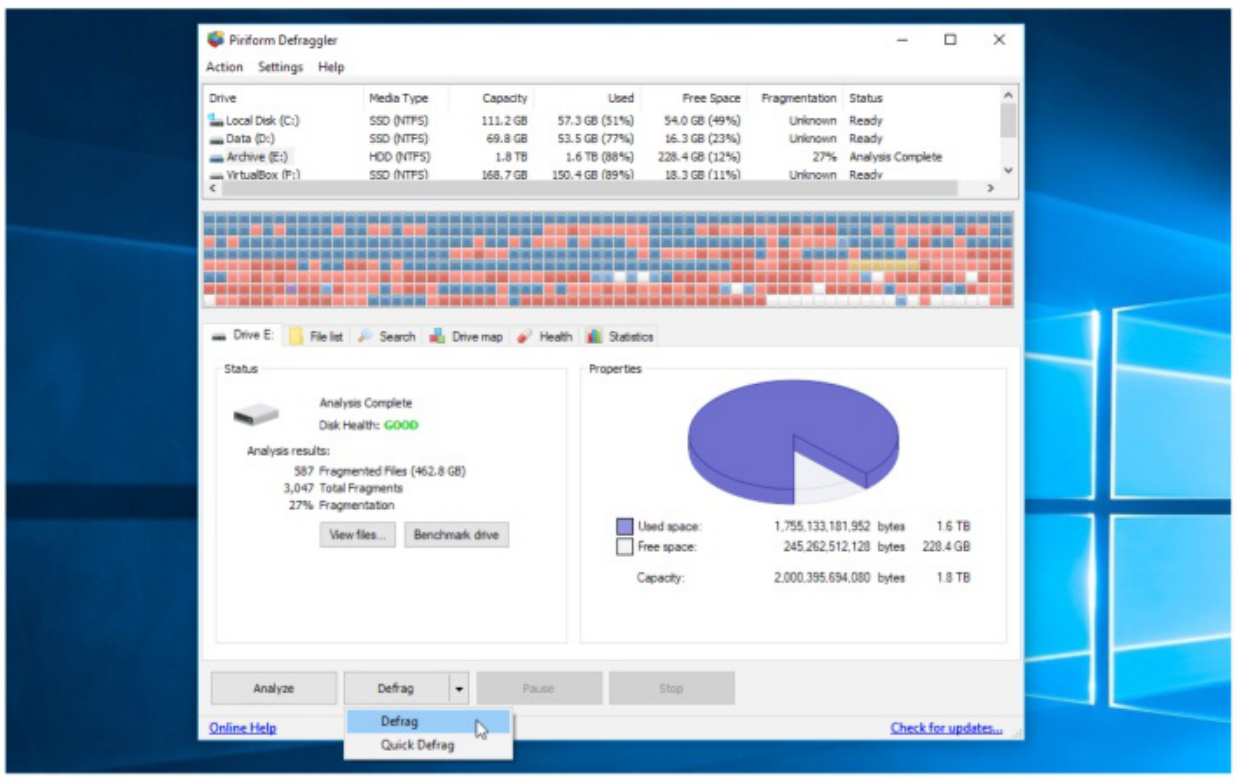
BootRacer also inserts a delay of 10 seconds to the startup process, to give Windows a chance to finishing loading before any startup programs are launched. This helps stop your PC being overwhelmed by demands for system resources.

EASY SERVICE OPTIMIZER

Services are special low-level programs that run in the background, performing numerous functions. Each one uses its share of system resources and—armed with the right know-how—you can selectively disable them to free up memory and processor time. But why do it by hand when Easy Service Optimizer (**www.sordum.org/8637**) can do the hard work for you?

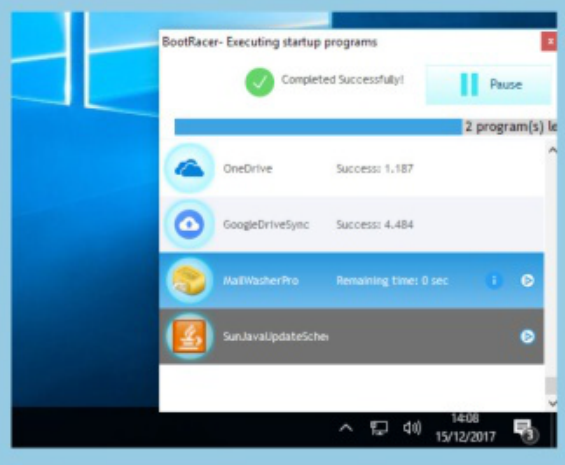
The program provides three presets: Safe, Tweaked, and Extreme. For most people, Safe is best—it's a "no-risk" option, and you can easily revert to Default if things stop working. Advanced users can go further, and the app enables you to manually tweak individual Services, too.





DEFRAGGLER

If you're still running Windows off a traditional platter-based hard drive, keeping it defragged is a must. Windows' own Disk Defragmenter does a good enough job, particularly in Windows 10, but if you want to squeeze even more performance out of your drive, Defraggler (**www.piriform.com**) is the tool to turn to. Not only can you opt to move large files to the end of the drive to help speed up performance, but Defraggler enables you to defrag individual files and folders, too—perfect for quickly defragging a single file without tying up your PC for hours. Defraggler also offers an "Optimize" option for SSDs, which manually wipes space marked for deletion to boost drive performance.

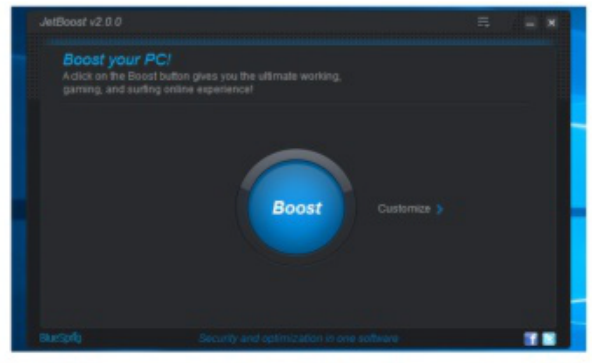


3 STAGGERED LOADING

BootRacer also loads programs in sequence, one after the other—again, to balance the demands on your PC. Click the three-line "hamburger" button to reveal a list of all the programs that are loading, along with their respective startup times.

4 MANAGE APPS

Click "Startup Control" from the main program to manage startup programs. You can disable or delete them from here, and rearrange their running order—for example, to get your faster-loading programs launched first.



JETBOOST

JetBoost (**www.bluesprig.com/jetboost.html**) is a tool that quickly shuts down unnecessary services and programs on a temporary basis only. For example, if you play demanding games or encode HD video, JetBoost can deliver a speed boost for the duration, then restore everything for normal operation after—all via its one-click button. Also handy for silencing intrusive apps and notifications while you work.

Overclock your PC

Push your PC's components to their limits and deliver noticeable speed improvements with these hardware-tuning apps.

While there's no substitute for hardware upgrades to deliver the ultimate performance boost, the fact remains that it's highly likely that various components within your machine aren't being pushed to their absolute limits. By default, many components are configured in a conservative fashion, but if you're armed with the right tools, you can start squeezing them that little bit further.

It's worth noting that overclocking your processor, RAM, and graphics can shorten the lifespan of those components, particularly if their core temperature rises. Thankfully, our recommended tools have built-in fail-safes and monitoring mechanisms, so you can check your tweaks aren't going to bring your PC to its knees.

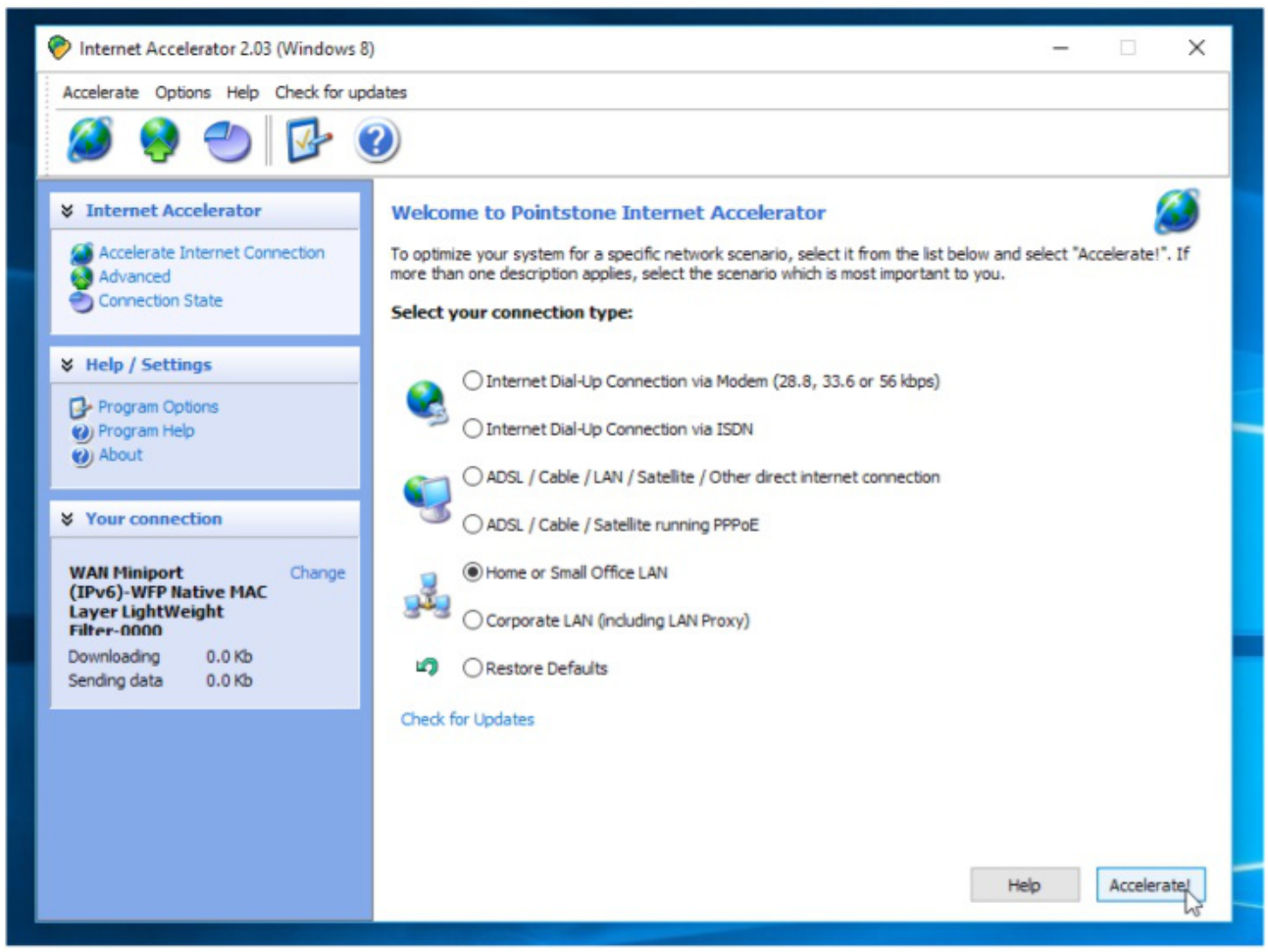
You can also speed up other hardware areas—without introducing undue stress. Expect to deliver minor speed bumps to your SSDs and Internet connection, and make sure you update your drivers, to ensure the latest, fastest ones are in place.

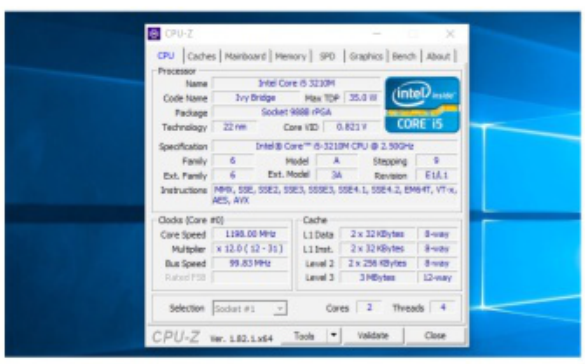
INTERNET ACCELERATOR 2

This free tool, which you can download from **www.pointstone.com/products/InternetAccelerator**, works best on older machines running Windows 7 or earlier. It's designed to make it incredibly easy to tweak various Windows settings relating to your network connection, which can have a positive effect on various Internet-related activities.

Using Internet Accelerator 2 can't physically increase the speed of your connection, of course, but it can optimize your settings to make full use of the bandwidth you have available. It ensures your downloads, web browsing, and so on are going as fast as they're able.

To use it, first select your setup type (home or small office LAN for most people), then simply click "Accelerate!" to see whether you can speed things up.


Internet Accelerator 2.03 (Windows 8)
Accelerate Options Help Check for updates
Internet Accelerator
Accelerate Internet Connection
Advanced
Connection State
Help / Settings
Program Options
Program Help
About
Your connection
WAN Miniport (IPv6)-WFP Native MAC Layer LightWeight Filter-0000
Change
Downloading 0.0 Kb
Sending data 0.0 Kb
Welcome to Pointstone Internet Accelerator
To optimize your system for a specific network scenario, select it from the list below and select "Accelerate!". If more than one description applies, select the scenario which is most important to you.
Select your connection type:
Internet Dial-Up Connection via Modem (28.8, 33.6 or 56 kbps)
Internet Dial-Up Connection via ISDN
ADSL / Cable / LAN / Satellite / Other direct internet connection
ADSL / Cable / Satellite running PPPoE
Home or Small Office LAN
Corporate LAN (including LAN Proxy)
Restore Defaults
Check for Updates
Help
Accelerate!

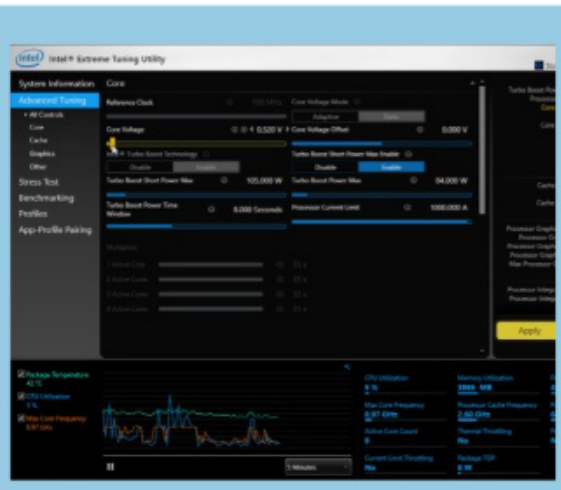


MOTHERBOARD TOOLS

If you self-built your PC, or know its motherboard make and model (find it with CPU-Z at **www.cpuid.com**), visit the manufacturer's website, where you may find tools for tuning or overclocking. Examples include A-Tuning (ASRock), AI Suite 3 (Asus), and OC Genie (MSI). You'll also find the latest drivers here.

BOOST YOUR CPU SPEED THE EASY WAY

One way you can speed things up is by overclocking your processor, so both it and your RAM run faster than they were designed to. There are dangers with this approach—overheating can shorten your components' lives—but official tools help to minimise the danger. AMD users should install AMD Overdrive (**www.amd.com/overdrive**); Intel users should download and install the Extreme Tuning Utility (**https://intel.ly/2y3DBw6**).



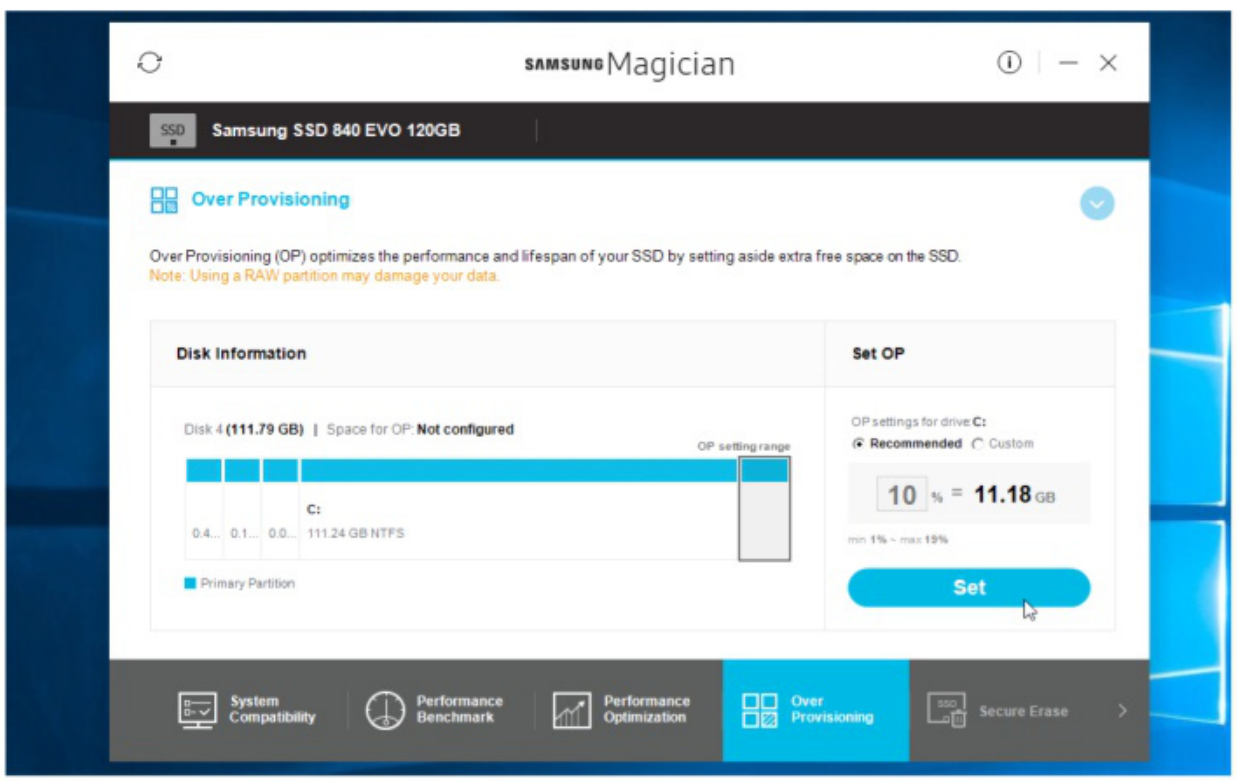
1 EASY OVERCLOCKING

Your overclocking options with Intel's utility vary according to the particular processor you have—some are incredibly limited, while others offer more scope. If supported, the utility can also enable you to overclock the onboard graphics.

MSI AFTERBURNER

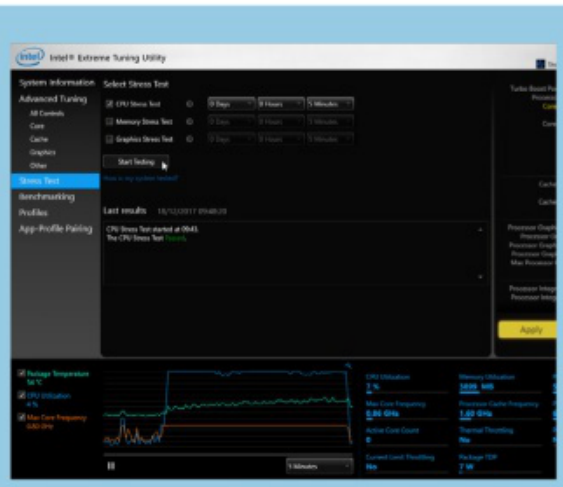
Overclocking your graphics card won't turn it into the latest model, obviously, but it can improve its performance, to make barely playable games run that bit more smoothly. If your PC comes with an AMD or Nvidia graphics chip, MSI Afterburner (**www.msi.com/page/afterburner**) has your back.

It works by enabling you to tweak your chip's clock frequency and voltage, while also giving you control over any onboard fans to help to try to minimize the temperature increase. Better still, there are real-time monitors to show you the effects of your overclock, too. Remember—you risk damaging your graphics card by overclocking, so use with care.



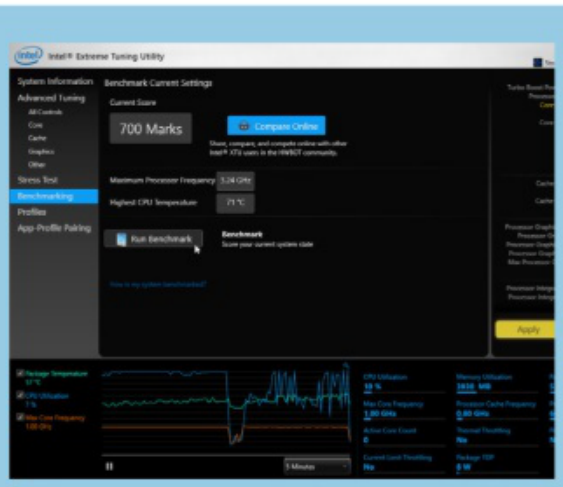
SOLID-STATE DRIVE (SSD) UTILITIES

Is your SSD drive running at its maximum? Be sure to visit your drive manufacturer to download and install any software tools. These alert you to health issues, provide firmware updates, and may offer settings to tweak performance. For example, Samsung Magician (**http://bit.ly/2CUTUt7**) offers a Rapid Mode switch, and Over Provisioning, which reserves space on your SSD to aid performance and lengthen lifespan. Similar tools can be found for OCZ (**http://bit.ly/2DnDgU4**), SanDisk (**https://bit.ly/2y4Hr88**), and Crucial (**https://bit.ly/2JEi7au**), among others.



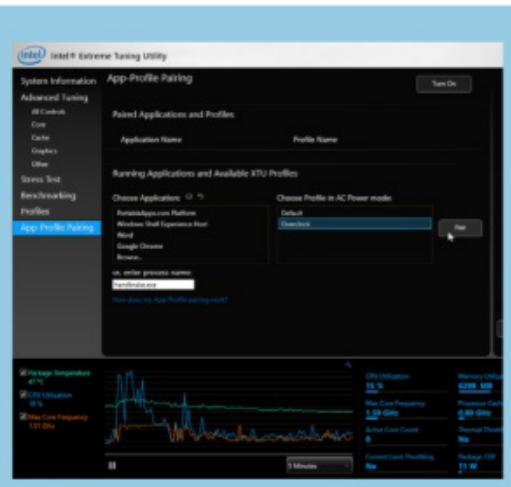
2 TEST YOUR OVERCLOCK

After tweaking your settings (visit **http://bit.ly/pcgoclock** for a detailed guide to what to do), select "Stress Test" to perform a five-minute stress test across processor, memory, and/or graphics, depending on what you choose to overclock.



3 BENCHMARK IT

Select "Benchmarking" to run a quick series of benchmarks to see the effects of your overclocking—benchmark before you start the process, and perform three benchmarks at a time, taking an average to give you a more accurate result.



4 APP-PROFILE PAIRING

Go to "Advanced Tuning" and click "Save" to create a profile of your overclocked settings. Pair it with an app under "App-Profile Pairing," so your PC is only overclocked when needed—for example, when playing games or editing 4K video.

Reinstall tools

Ensure your next Windows reinstall goes without a hitch with the help of these essential tools and utilities.

When you next come to reinstall Windows, it pays to take precautions in the form of various backups—File History is essential for personal data, but what about program settings, and how about a fail-safe backup in the event of a botched reinstall?

The reinstall process is also a good excuse to make changes to the way you organise data on your PC's main internal and external drives, while you'll also want to make sure that you have the latest versions of the Windows installation files, to save you a lengthy post-install update process.

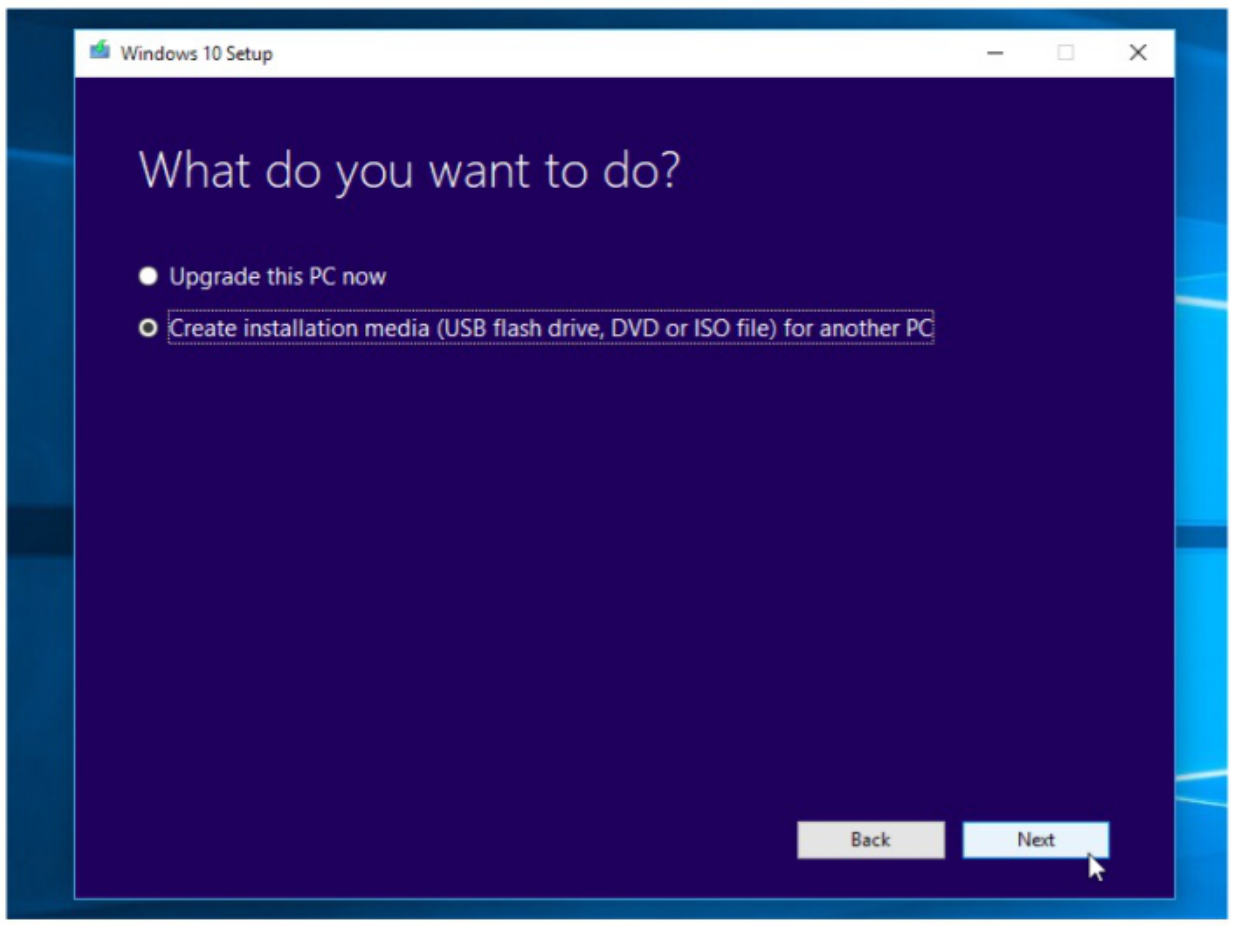
All these potential problems are covered by our favorite reinstall tools. You'll find the best drive backup tool in the business rubs shoulders with our free partition editor of choice and the Windows Media Creation Tool, which ensures you have the latest version of Windows 8.1 or 10 on your PC.

Throw in a couple of other handy applications we've tracked down for you, and your next Windows reinstall just got a whole lot simpler (never mind safer).

WINDOWS MEDIA CREATION TOOL

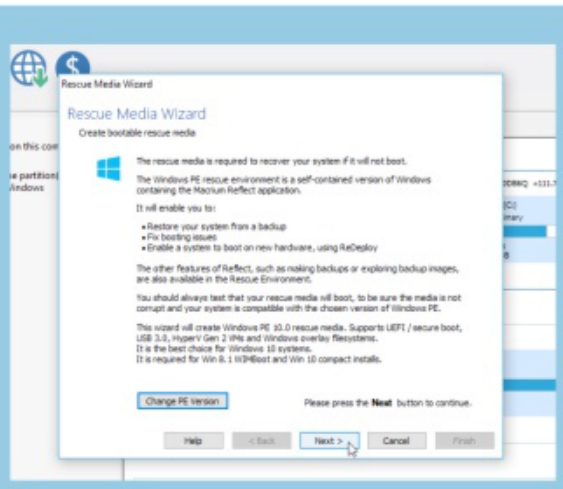
The days of relying on an increasingly out-of-date installation disc are long gone. Simply download the Windows Media Creation Tool for Windows 8.1 (**www.microsoft.com/software-download/windows8**) or Windows 10 (**www.microsoft.com/software-download/windows10**), and it will walk you through the process of creating your reinstall media, either on DVD or a USB flash drive.

Better still, the Windows Media Creation Tool also downloads the latest installation files first, which means that if you reinstall Windows 10, for example, you get it with the Fall Creators Update already applied. Always create fresh media prior to reinstalling Windows, to ensure you have the latest version of the operating system.


Windows 10 Setup
What do you want to do?
Upgrade this PC now
Create installation media (USB flash drive, DVD or ISO file) for another PC
Back
Next

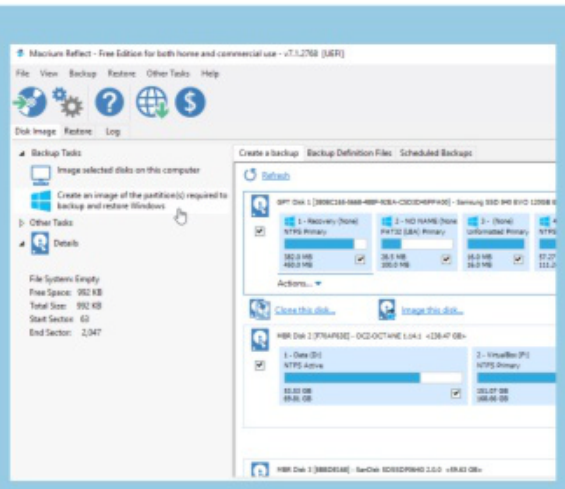
TAKE A BACKUP WITH MACRIUM REFLECT FREE

Reinstalling Windows from scratch is a one-way process. Once you've formatted the drive and reinstalled Windows, everything you once had is gone. What happens if you forget a key file or setting, or the reinstall process goes wrong, and you want to roll things back? Don't worry—Macrium Reflect Free (**www.macrium.com/reflectfree.aspx**) is just the tool for you. Here's how you can use it to protect yourself and your files.



1 SORT RESCUE MEDIA

Launch Macrium Reflect Free and choose "Other Tasks > Create Rescue Media" to create a bootable DVD or USB flash drive you can use to recover your Windows installation if something goes catastrophically wrong with your PC.



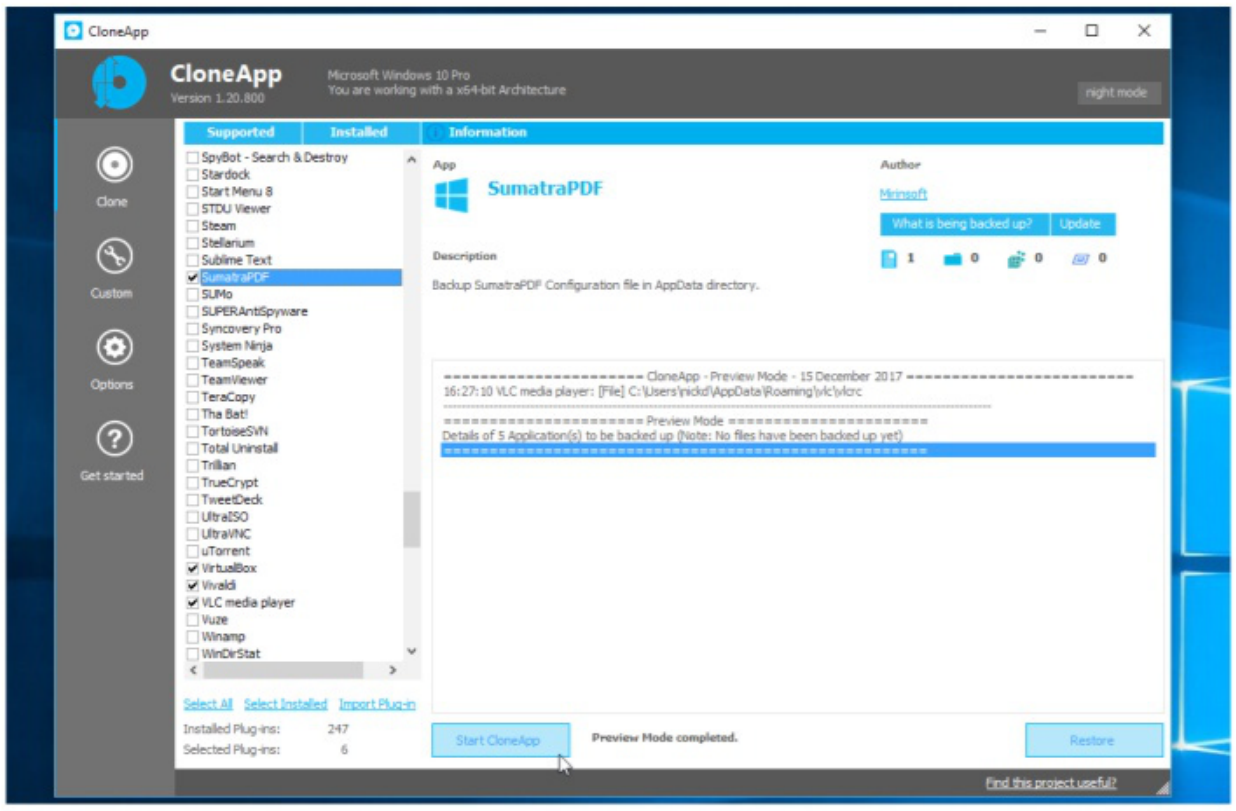
2 BACK UP PARTITIONS

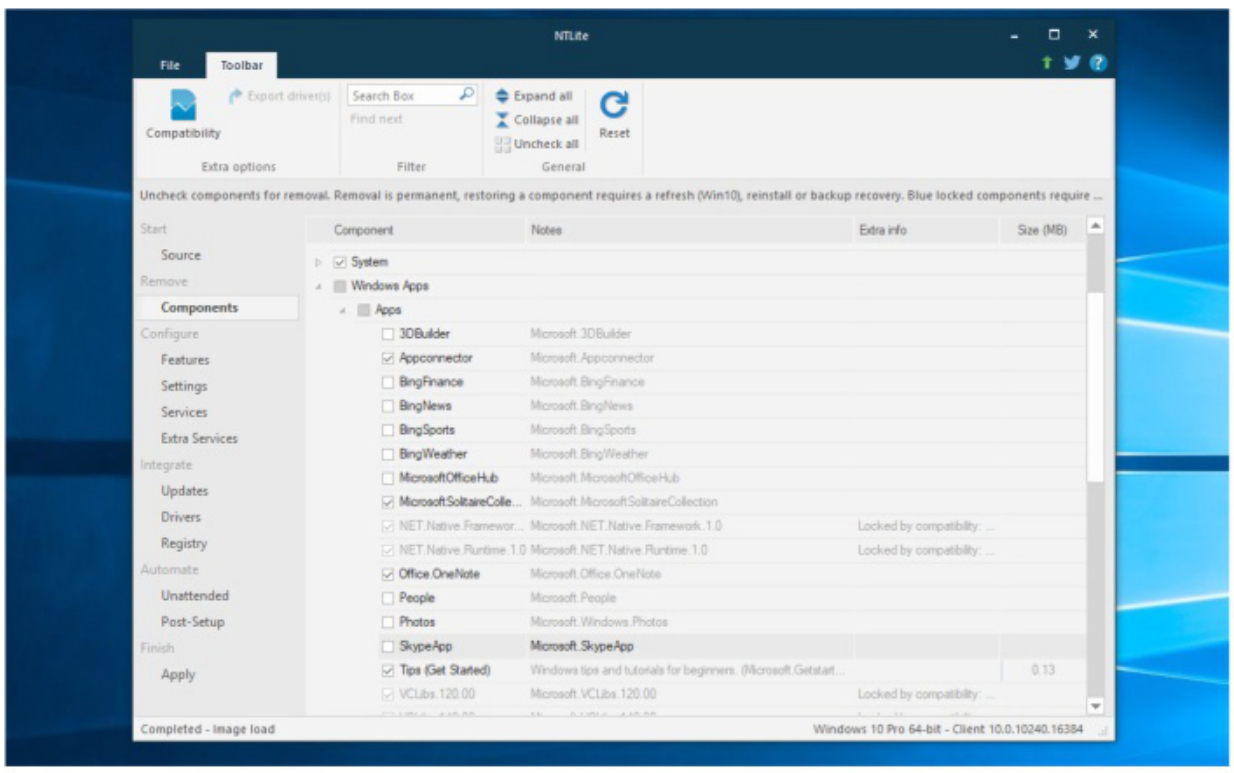
Once you've created your rescue media, click "Create an image of the partition(s) required to backup and restore Windows"—Macrium automatically selects your Windows partition, along with boot partitions required to boot your PC.

CLONEAPP

One of the most time-consuming tasks after reinstalling Windows is restoring program settings. CloneApp (**www.mirinsoft.com**) enables you to selectively back up key directories and Registry settings where apps store their preferences. Nearly 250 program and Windows settings are plugged into the program—just locate your app, check the box, and it backs everything up, but you can also add your own custom files and Registry entries, too.

Once Windows and your apps have been reinstalled, just launch CloneApp and click "Restore" to put everything back again. To selectively restore program settings, open the CloneApp\Backup directory, and remove any settings you want to exclude before running CloneApp.

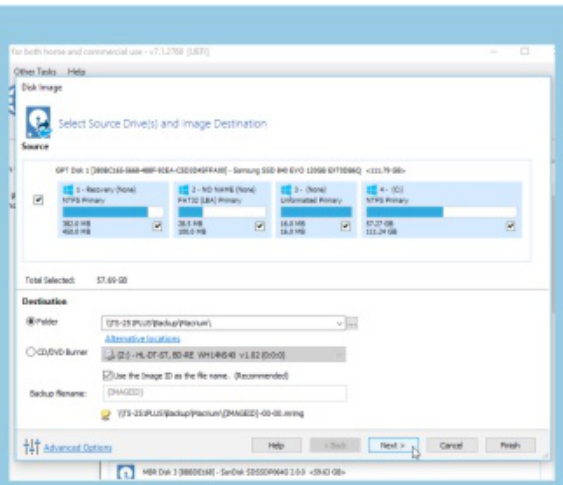




NTLITE

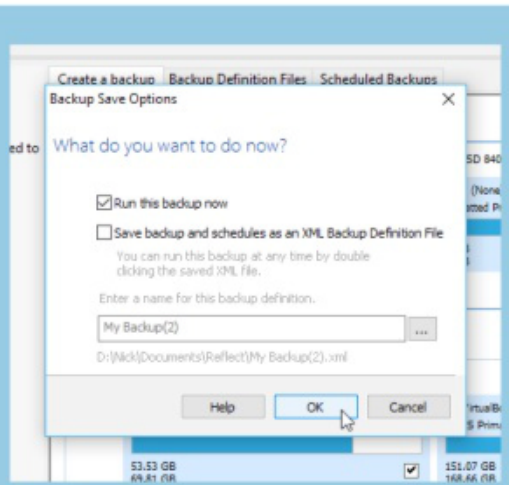
Advanced users may feel frustrated at constantly having to tweak Windows after installation. NTLite (**www.ntlite.com**)makes it possible to build customised Windows 7, 8.1, or 10 installation media that not only has all the latest updates included (a boon for Windows 7 users), but which is tailored to your needs, too: You can integrate specific driver packages, remove unwanted Windows components (with built-in safety mechanisms to protect you from inadvertently removing stuff you might need), and perform various tweaks.

Certain features are restricted in the free edition—purchase the full version, and you can even perform these tweaks on your current Windows installation, for example.



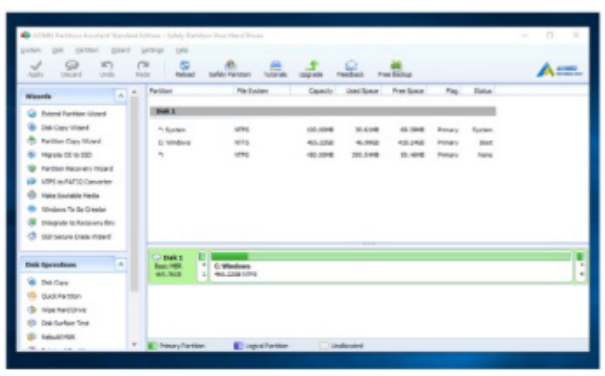
3 CHOOSE A LOCATION

Click the ellipsis (...) next to "Folder" under "Destination" to select a suitable folder on your backup drive for the partition image. Click "Advanced Options," then check "Verify image..." under "Auto Verify Image," before clicking "OK," followed by "Next."


Create a backup
Backup Definition Files
Scheduled Backups
Backup Save Options
What do you want to do now?
Run this backup now
Save backup and schedules as an XML Backup Definition File
You can run this backup at any time by double clicking the saved XML file.
Enter a name for this backup definition.
My Backup(2)
D:\Nick\Documents\Reflect\My Backup(2).xml
Help
OK
Cancel

4 CHECK AND BACK UP

Ignore the Schedules screen—this is a one-time fail-safe backup prior to reinstallation. Click "Next," review the backup settings, and click "Finish." Uncheck "Save backup..." and click "OK" for Macrium to back up and verify the image.



PARTITION ASSISTANT

AOMEI's Partition Assistant (**www.aomeitech.com**) enables you to divide your PC's storage drive into two or more partitions. Why partition your drive? It enables you to separate personal data from Windows and apps. When you next come to reinstall Windows, your files are already safely stored on another drive.

A full, destructive reinstall

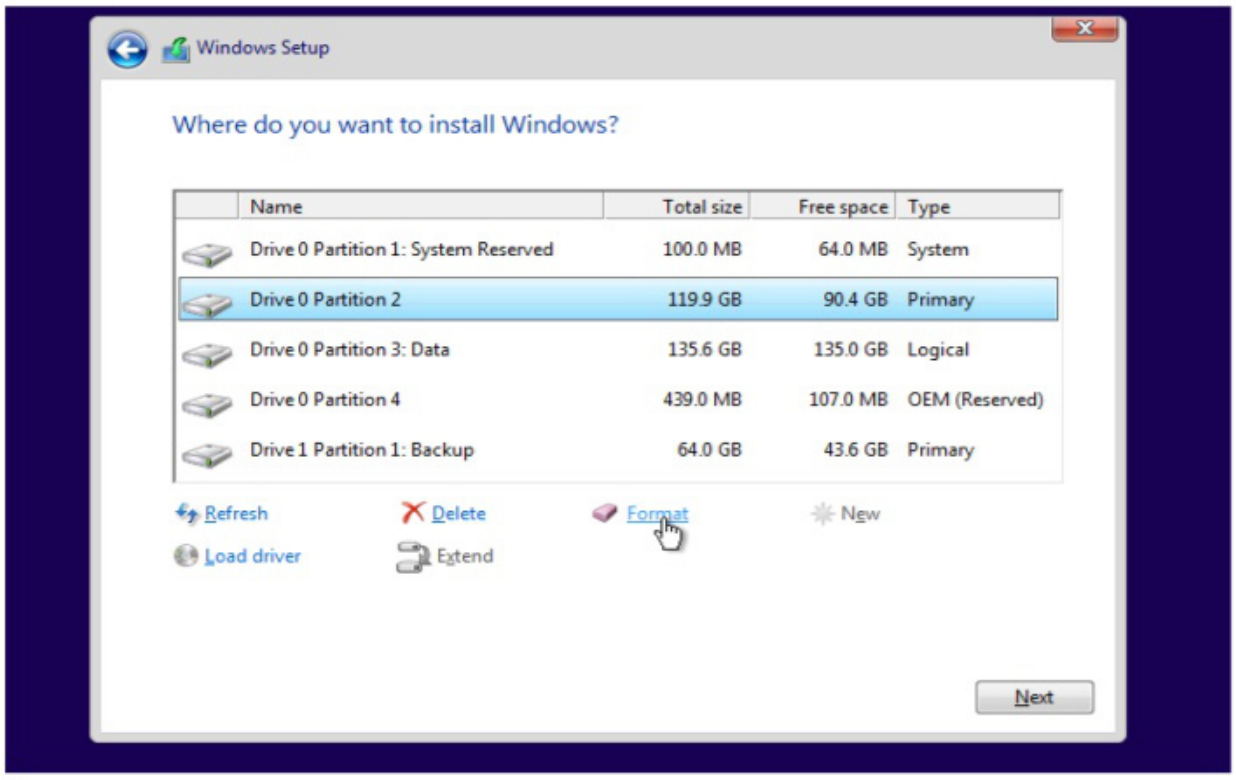
If you're looking to wipe the slate clean, or need to recover from major issues, the nuclear option is always best

Reinstalling Windows from scratch—wiping your system drive clean to install a brand-new (and fresh) version of Windows on it—is the ultimate choice for anyone looking to revive a slow-running PC or resolve a major, non-hardware issue, such as those caused by malware or a clogged-up computer. In this section, we walk you through the entire process.

Ideally, you should have a recent and full backup of your PC, created using either File History or the Windows Backup and Restore tool, before you begin. That way, you'll lose the minimum of content. A full reinstall really is destructive—nothing left on your C drive will exist once you've finished. You should ensure you have the latest installation media for your target version of Windows—see our section on the Windows Media Creation Tool on page 32 for tips on how to do this. This ensures a cleaner, more up-to-date installation from the get-go, saving you time bringing it fully up to date once the installation has completed.

It's also worth sourcing networking and graphics drivers now rather than relying on Windows to provide them—in most cases, they should be built in, but not always. Consult your PC or mobo manufacturer's website for these, or visit your Wi-Fi adapter or graphics card manufacturer's site, and download them to your backup drive.

Other things to consider: Uninstall any products that require activation at this point—this should deactivate the licenses, and enable you to use them with your new install without any issues. Also, be sure to have product keys and program installers to hand.



▲ **Windows 10 users can launch a repair install directly from the Media Creation Tool.**

STARTING THE REINSTALL PROCESS

A full destructive reinstall should always be started by booting from your installation media, be it a DVD or USB flash drive. The actual reinstall process doesn't differ much across Windows 7, 8.1, or 10. You are asked to verify your language, location, and keyboard are set correctly, then it's a case of clicking "Install Now." If prompted, enter your product key, or click "Skip" if you're running Windows 10 on a PC you upgraded during the free period. When asked what type of installation you wish to perform, choose the "Custom" option.

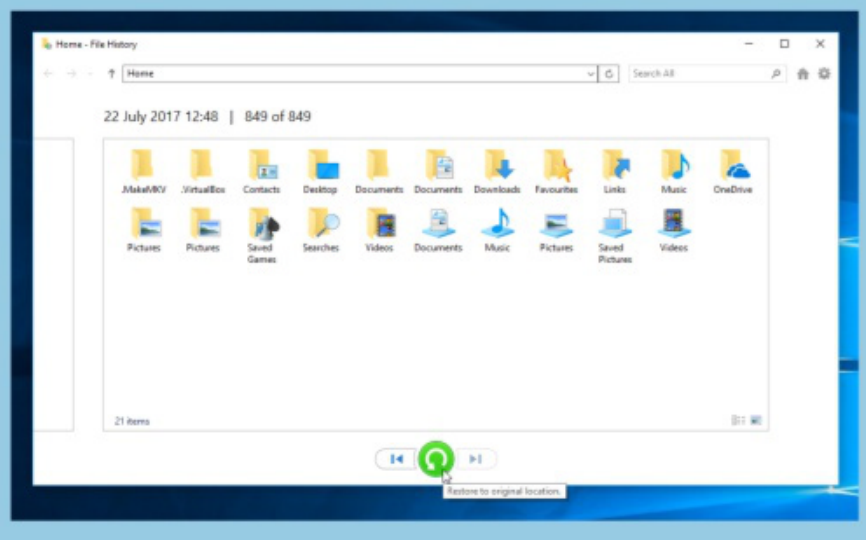
Next comes potentially the trickiest part of the process. A list of drives and partitions appears—you need to select the one on which Windows is currently installed. By default, it should be detected and selected, but verify it's correct before clicking "Format" (click "Advanced Drive Options" if it's not visible).

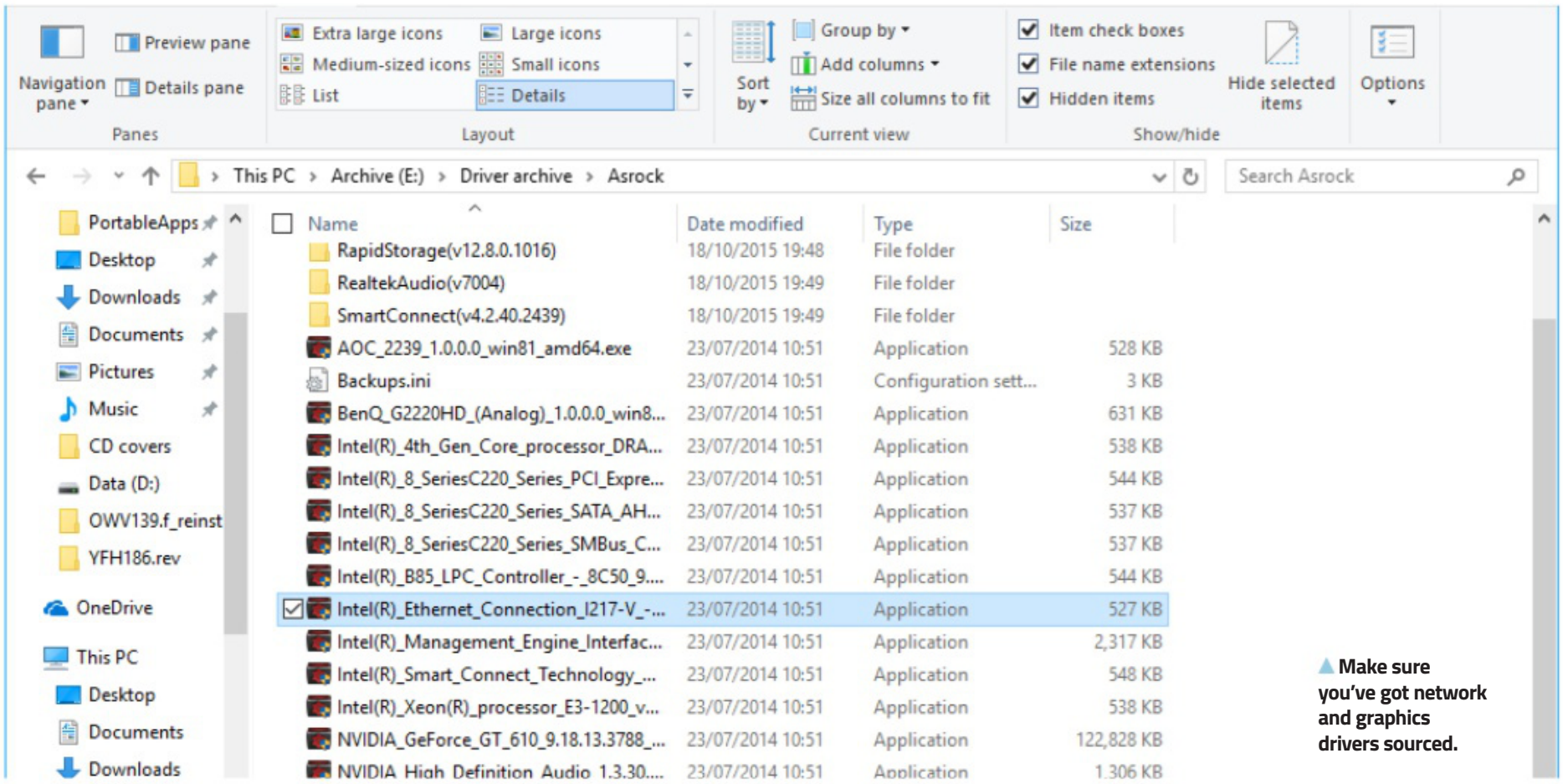
RESTORE PROGRAMS, SETTINGS, AND DATA

Once Windows has been reinstalled, open Windows Update to bring your fresh operating system fully up to date—don't be surprised if there are hundreds of updates still to apply in the case of Windows 7 and 8.1. Once it's completely updated, consider reinstalling Macrium Reflect Free (see page 32), and taking your first drive image—a vanilla backup you can restore in future if needed, instead of reinstalling Windows itself.

If you followed the advice on page 33, you should be able to reinstall your core apps using CloneApp from your PC's data drive. If you click "Restore," every program setting you backed up is restored—if there are any you don't want to restore, select "Options" to locate the backup folder, then open it, and move any program folders you want to ignore out of the folder temporarily, before clicking "Restore." Once done, take your second Macrium Reflect Free backup.

Finally, open File History or the Windows Backup and Restore tool, and take the necessary steps to restore any data you backed up, then make sure that either tool is configured to carry on backing up all your precious files going forward.





▲ **Make sure you've got network and graphics drivers sourced.**

Click "OK," then once formatted, verify the drive is still selected, and click "Next."

That's the technical stuff pretty much done. You'll see a checklist of tasks to be performed—just sit back and wait. One thing to note: When Windows reboots, you may see the "Press any key" prompt again to boot from CD or DVD. Don't press anything if that happens, just let the installer continue.

> "A full destructive reinstall should always be started by booting from your installation media, be it a DVD or USB flash drive."

SET UP POST-INSTALL

The post-setup prompt begins with Windows 7 users being prompted for their product key, then it's a case of setting up a user account, and you're off and running. Windows 8.1 users get an "Express Settings" prompt—be sure to click the option to customize these, and make sure you go through them carefully.

Post-Creators Update, Windows 10 no longer gives you an "Express Settings" option. For now, confirm your location and keyboard, set up your network if required, and choose "Personal use" when prompted. You can either sign in with your Microsoft account, or click "Offline account > Maybe later," if you plan to stick with the old-style Windows 7 local user account.

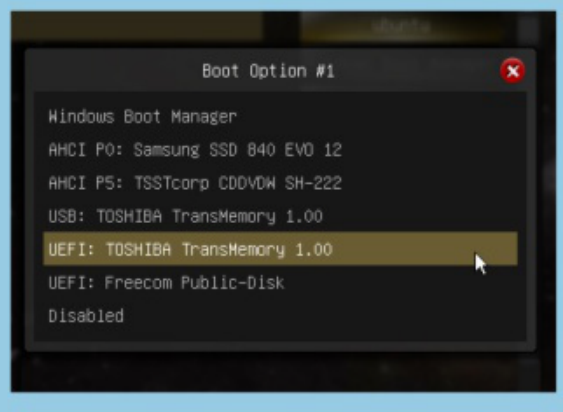
If you opt for the Microsoft account option, now is a good time to set up a PIN to speed up future logins. (Note: The PIN is tied, specifically, to this PC, and you can always bypass it using your regular account password should you forget it at any point.)

You're then asked to set up Cortana—this is where Windows 10's notorious privacy settings come into play, so review all of the options carefully, flicking the slider to "Off" for any you don't need or use.

That's the end of the setup process—Windows now configures itself based on your choices, and you'll see a series of messages appear. Eventually, you'll find yourself back at the Windows desktop. PC

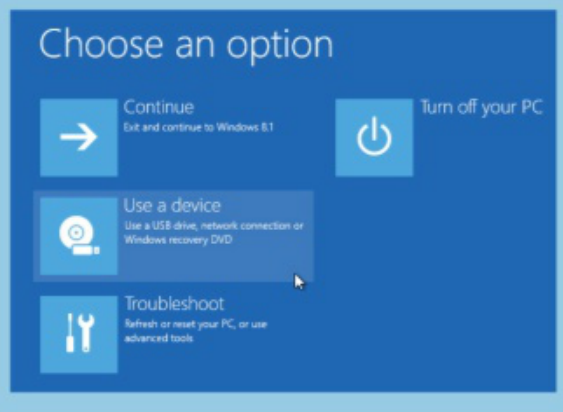
2 REBOOT FOR MEDIA

If you're running Windows 7, or have Fast Boot disabled, insert your boot media, and start your PC. Look for a "Press any key to boot from CD or DVD" option—even if you have booted from a USB flash drive. Press any key on your keyboard, and you should find that the Windows install process starts.



3 TWEAK BOOT OPTIONS

If you boot back into Windows, restart your PC again, but this time press a key, such as F11, when prompted, to open a boot menu. Once you have done so, select your boot media—choosing "UEFI" if that option appears—to boot; otherwise, enter setup so you can change the boot device order.


Choose an option
Continue
Exit and continue to Windows 8.1
Turn off your PC
Use a device
Use a USB drive, network connection or Windows recovery DVD
Troubleshoot
Refresh or reset your PC, or use advanced tools

4 WINDOWS 8.1/10

If Fast Boot is enabled on your computer, open "Settings" in Windows, then navigate to "Update & recovery > Recovery," then click "Restart now" under "Advanced startup." When the boot options appear, choose "Use a device" to select the USB drive or DVD you created from the list that appears.

Play classic games with DOSBox

Get your retro on, with Nate Drake.

If you lived through the '90s, you probably have fond memories of gaming classics such as Red Alert, Doom, and Starcraft. Despite the clunky graphics and witless AI, it's hard to recapture the sense of excitement that came from giving Stalin a bad day, or battling against the forces of hell on the moons of Mars. Sadly, most of these vintage gaming classics don't work natively on modern PCs. This dilemma is the focus of the DOSBox project, an emulator designed to mimic Intel x86. The emulator's primary focus is to play games that were released prior to Windows XP (2001), but in practice, you can actually run a number of DOS/Windows programs. The DOSBox website maintains a database of all supported software (**www.dosbox.com/comp_list.php?letter=a**).

You'll notice that DOSBox bears an uncanny resemblance to MS-DOS itself. This is all part of the fun: You only need to master a few commands to relive your gaming glory days. In this guide, you'll discover how to get started, as well as how to access more advanced options. We also cover how to connect a gamepad or joystick, as well as how to configure DOSBox for LAN gaming.

1 INSTALL AND LAUNCH DOSBOX

To get started with DOSBox, open your web browser, and navigate to **www.dosbox.com**. Select the "Downloads" tab, then click the green "Download Now" button. Once the download is complete, open your downloads folder, and double-click to launch the DOSBox installer. Click "Yes" to allow Windows 10 to begin installation. Click "Next" to continue, then do the same when DOSBox asks you to choose which components to install.

Click the "Install" button to finalise installation. A shortcut to DOSBox now appears on your desktop.

2 PREPARE GAME FILES

For security reasons, DOSBox can't access your disk drives directly. Instead, it mounts folders as virtual drives. If you have multiple games, consider creating the folder "C:\GAMES" or similar, so you can access all your titles from one place. For the purposes of this guide, we've used a shareware version of the first-person shooter Doom 2 (available from **www.dosgamesarchive.com/download/doom**).

If you are lucky enough to still own the original CD of a particular game, such as Tomb Raider II, but don't have regular access to an optical drive, you need to create an ISO image, so DOSBox can access it. Utilities such as Alcohol 120 can do this for you. See **http://support.alcohol-soft.com/knowledgebase.php?postid=27806** for more information.

Copyright law in some countries permits software owners to copy disks to a new medium for their own use—for example, by creating an ISO, as outlined above. Some states also permit downloading games from what are known as "abandonware" websites, because the copyright holder no longer exists. Take some time to research what's legal in your jurisdiction before proceeding.

3 MOUNT AND RUN YOUR FIRST DOSBOX

Double-click the DOSBox icon on your desktop to launch the emulator. If you've previously used MS-DOS, the interface should look reasonably familiar [Image A], but bear in mind that DOSBox only recognizes a few MS-DOS commands.

Begin by mounting your game folder as the C virtual drive—for example:

```
mount C C:\GAMES\DOOM2
```

If your game is stored on an ISO, mount it as virtual drive "D" with imgmount so the command becomes:

```
imgmount D C:\GAMES\STARCRAFT.iso -t iso
```

Once your virtual drive is mounted, switch to it by running the command:

```
C:
```

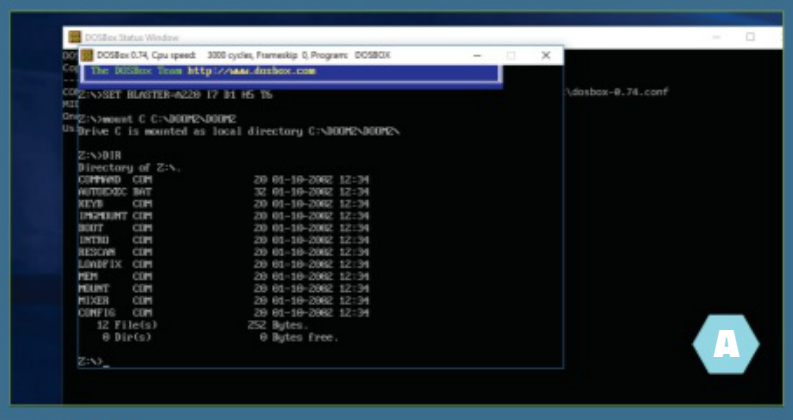
For ISOs run:

```
D:
```

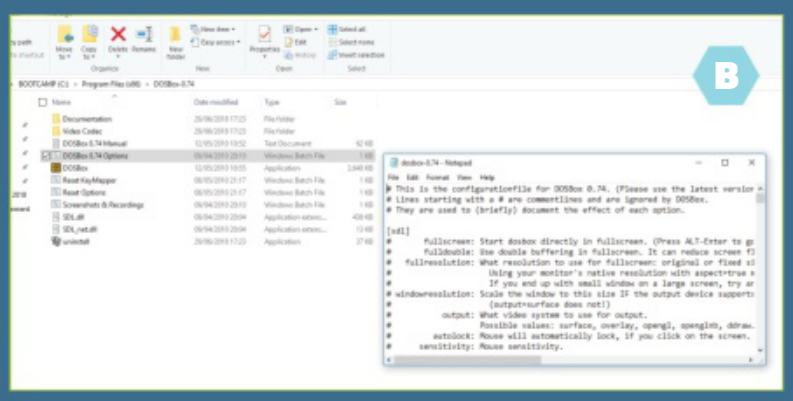
You next need to run either the game executable or the corresponding setup program to install the game files. Use the following command to list all the files and folders in the current directory:

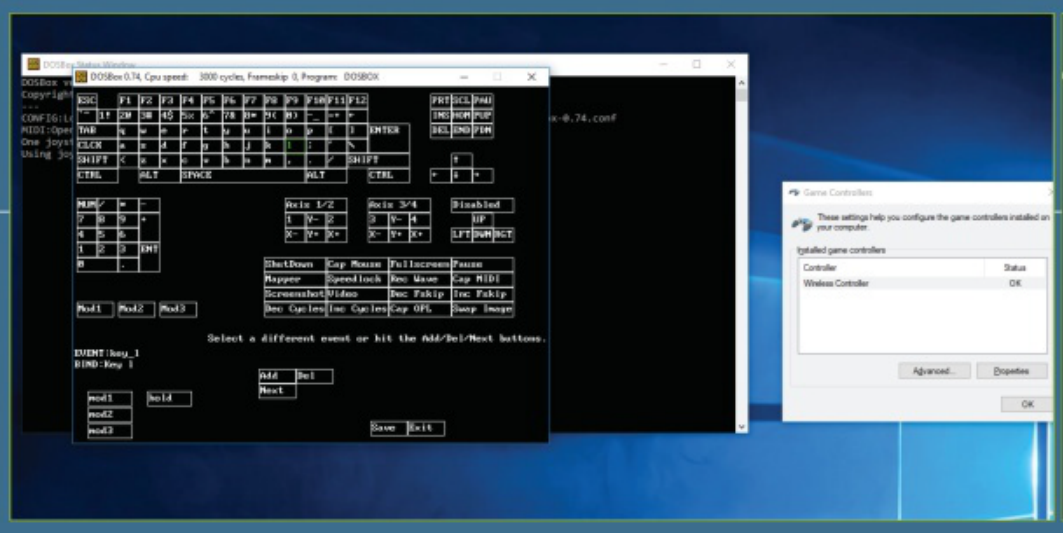
```
DIR
```

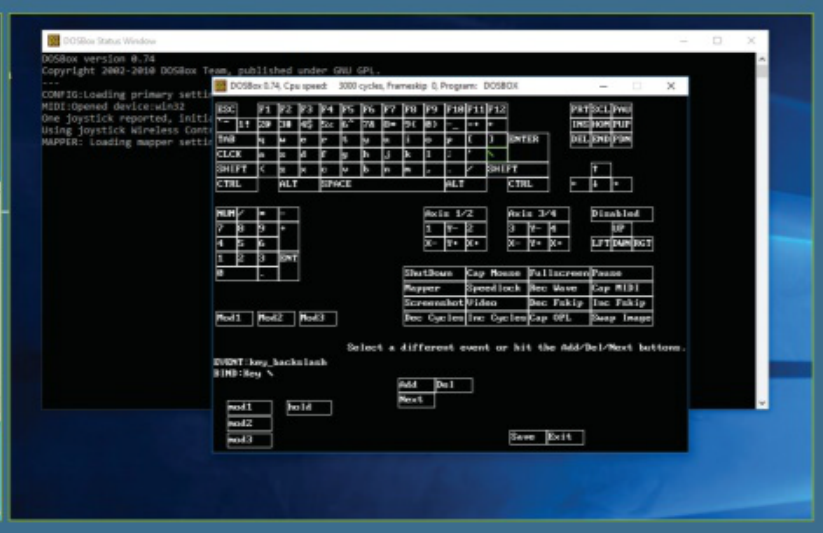
You can use this command to switch



> Despite the clunky graphics and witless AI, it's hard to recapture the sense of excitement that came from giving Stalin a bad day







to a new directory:

```
CD <FOLDERNAME>
```

Once you've located the correct file, run it by typing the full name—for example:

```
DOOM2.exe
```

4 ACCESS DOSBOX CONFIGURATION SETTINGS

All DOSBox emulation settings are managed via the "DOSBox.con" text file [Image B]. In Windows 10, you can find this file within your "AppData" folder—for example, C:\Users\Nate\AppData. DOSBox should also display the location of your configuration file inside the main window when you launch the emulator. If the file doesn't yet exist, you need to open DOSBox, and run the following command to create a configuration file in your directory:

```
config -writeconf dosbox.conf
```

Open the file "C:\Program Files (x86)\DOSBox-0.74 Options.bat" to view the DOSBox configurations in Microsoft Notepad. Each separate option is listed on its own line. Those lines that begin with "#" are ignored by DOSBox. However, you can read these lines to explore what each option does and view any alternative settings. For instance, output can be set to opengl , which offers faster performance, but potentially more blurry graphics. You can also toggle simpler options, such as setting fullscreen=true , for example.

You'll get the very best from your emulation experience by customizing your configuration for each game you play through DOSBox—it supports multiple configuration files. To launch the emulator with a specific one, use the command-line argument -conf w . The simplest way to do this is by modifying the DOSBox desktop shortcut.

5 GAMEPAD CONFIGURATION

DOSBox supports many game controllers and joysticks out of the box. In the configuration file, joysticktype is set to auto by default, enabling automatic detection of devices. If you have a specific type of controller, you can specify this here as well. Visit the DOSBox manual for a full rundown of these options (**www.dosbox.com/DOSBoxManual.html#Joystick**).

Before you can use your gamepad with DOSBox, you must also ensure it can be detected by Windows. First, connect the controller to your USB port. In Windows 10, a notification should appear automatically to say that the device is connected. For this tutorial, we used a PS4 wireless controller connected by USB cable.

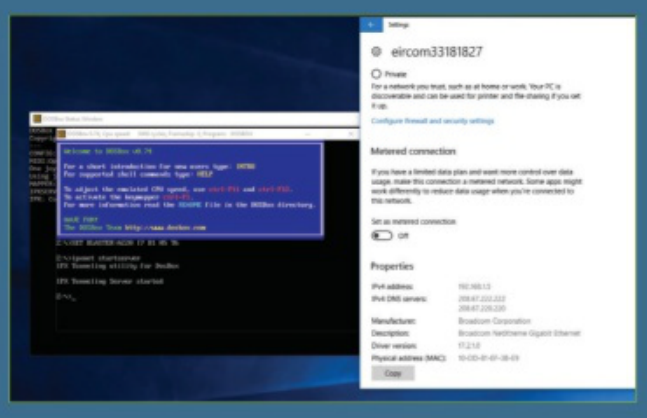
To check your gamepad is working, click the Windows 10 "Start" menu, and enter "game" in the search bar. Next, click "Set up USB game controllers." This opens the control panel, and your gamepad appears. Click "Properties," then open the "Settings" tab to access the calibration options.

Only certain DOS games are configured to work with joysticks and gamepads. For instance, Doom works with the keyboard by default. If you want to use a modern controller with a classic DOS game, press Ctrl-F1 when running DOSBox. This opens the "mapper" [Image C]. From here, you can bind gamepad buttons to keys. For instance, to bind the S key on your keyboard to the "Down" button on your controller's Dpad, use your mouse to click on the key in the mapper window, select "Add," then hold "Down" on the Dpad. Repeat this process for each of the keys used in game. Click "Save" when done to store your settings.

6 ADVANCED TWEAKS

One of the most common complaints of DOSBox users is that they can't find the all-important backslash (\) on their keyboard, which is necessary for accessing files and folders. The easiest workaround is to use the mapper, as outlined in the previous step, to reassign backslash to another keyboard key [Image D].

Certain DOS programs may require more memory than the amount DOXBox allocates by default (16MB). You can alter this by accessing the configuration options as outlined in Step 4, then changing memsize=16 to something more suitable. PC



DOSBOX MULTIPLAYER

DOSBox is capable of emulating the IPX (Internet Package Exchange Protocol), which was used for playing network games in classics such as Doom and Quake. In simplest terms, one computer acts as the games server to which other players can then connect. To get started, open the file "C:\Program Files (x86)\DOSBox-0.74 Options.bat" to access the DOSBox configuration. Scroll down to ipx=false and change it to true to enable IPX.

Next, open DOSBox on the machine you want to use as a server, and run the command ipxnet startserver . Ask each of the players on your local network to launch DOSBox and run the command ipxnet connect <ip> , where "ip" is the local IP address of the server. In Windows 10, you can find this by opening the Start menu, and searching for "Ethernet." Select your network name from the menu. A window opens displaying your IPv4 address under "Properties." You should now be able to host a match using the in-game options.

Thermaltake WaterRam RGB

KEEP COOL IN STYLE.

As the Australian summer winds down, it can be easy to forget that your PC is still generating plenty of heat, especially if you're running all the latest games on it. When you've got all the best parts and you've maxed out the graphics settings on Battlefield V, it's important that you protect the innards of your PC as much as possible. Water cooling is the best way to ensure that your PC stays cool even when things get intense, and that your PC is less likely to suffer from overheating. Thermaltake's latest product, the WaterRam RGB, is RAM memory that will keep its cool under pressure. But it's not just the unique water block that makes the WaterRam RGB a great choice – it's also extremely fast, efficient RAM in its own right.

THE WET STUFF

Thermaltake is a market leader on water cooling support for your PC. Because liquid coolants have a higher heat capacity and thermal conductivity than the air pushed around by internal fans, they allow your PC to run at greatly reduced temperatures with less chance of overheating or part failure. The new Thermaltake WaterRam RGB is the easiest RAM on the market to keep cool, thanks to Thermaltake's integrated solutions, which let you plumb the RAM into your PC's liquid cooling easily.

The WaterRam RGB Liquid Cooling Memory is an all-in-one solution – no RAM before it has come with a built-in water block for cooling, and there's a good chance it represents the future of RAM cooling solutions.

The attached water block is high quality, made from a CNC machined cooper base, with a PMMA cover and anti-corrosive nickel plating. It's designed to last, and to allow for the highest water flow possible. The WaterRam features high speed DDR4 3200MHz memory and comes in two kit-sizes - 16GB (8GB x 2) and 32GB (8GB x 4). It comes Intel XMP 2.0 ready, making one-click overclocking possible.

HOW IT WORKS

The technology inside the WaterRam RGB is state of the art, allowing for the best experiences with gaming and any other activities or programs that are going to push your PC to the max. This is high-speed, low-latency RAM, with carefully screened Hynix C-die ICs. It has low CL16 latencies, meaning that it runs fast, and it has been tested on Intel's latest DDR4 motherboards for the best performance possible. With the WaterRam RGB, you're getting RAM that not only runs cool – it can also kick your PC up to the next level.

The WaterRam RGB features a hybrid cooling kit that allows for

> **There's an astonishing 16.8 million colours available, as well as varying lighting modes and levels of brightness.**

two-way heat dissipation, through both its liquid cooling and its high quality 2mm aluminium heatsinks. While most other RAM on the market uses double coasted tissue tapes, the WaterRam RGB features superior thermal pads, allowing for stronger thermal conductivity and weight endurance. It's because of these pads that the WaterRam RGB can support Thermaltake's unique water block. If you haven't rigged your PC for water cooling yet, the heatsinks will still help to keep your RAM cool in the meantime. Under a heavy load, the Thermaltake WaterRam RGB can decrease temperatures by up to 37%, from the 48C you might experience without cooling down to just 30.2C. Results might vary depending on system specs, but you'll see significant drops in temperature when your PC is being pushed to its limits. Your RAM is important, and with the WaterRam RGB you have peace of mind – overheating can significantly damage your RAM, as well as the motherboard and other adjacent parts. Your RAM comes with a lifetime warranty, and the water block attached comes with a two-year warranty, just to be extra safe.

LIGHT UP YOUR RIG

Thermaltake is a market leader on RGB products, making some of the most attractive PC parts and coolest light displays on the market, and the WaterRam RGB is no exception. It features 12 high lumens, addressable LEDs. There's an astonishing 16.8 million colours available, as well as varying lighting modes and levels of brightness. It can integrate right into the existing infrastructure of your PC if you've equipped it with other parts in the ThermalTake RGB range, and the lighting can be controlled through the Thermaltake TT RGB PLUS controller. Depending on your set-up, it's also compatible with ASUS Aura Sync, GIGABYTE RGB Fusion, MSI Mystic Light Sync, Razer Chroma, and AsRock Polychrome.

As long as you have a compatible volt motherboard, you can control the lighting via software. You can sync it up to music or plan out a colour palette for a game, and it's even compatible with Amazon's Alexa voice service, as well as Thermaltake's own AI Voice Control. The WaterRam RGB comes packaged with an RGB controller, and features its own 32-bit microcontroller unit, which gives you superior control over your water block and the programs it's compatible with. It all makes for a uniquely beautiful RAM set-up.

The Thermaltake WaterRam RGB is the first of its kind, and it's the exact kind of innovation that makes the PC marketplace so exciting. Not only does it offer a safer, cooler RAM solution, but Thermaltake's RAM is powerful and fast enough to boost your PC's overall performance. The WaterRam RGB is ahead of the PC cooling curve, and a great way to get the best performance possible out of your PC without having to worry about it overheating.

If you're putting together a PC with RGB lighting in mind, and you want or have a water cooling solution in place, it's going to be the best RAM for your build.

> **Under a heavy load, the Thermaltake WaterRam RGB can decrease temperatures by up to 37%, from the 48C you might experience without cooling down to just 30.2C.**

Games for 2019

From heavy gunfire to forest spirits, here are our top tips for 2019 By Ian evenden.

Sequels and remakes, sequels and remakes. It's been a criticism of the games industry for some time that it's averse to taking a risk on something new, more content to rake over the past, and present the familiar and "safe." This has been particularly true ever since the idea of the "HD remaster" came into being, with old games being polished up for modern graphical standards—to varying degrees of success—before being set before consumers as something new.

There is innovation—if you know where to look. The coming year sees a raft of Japanese games arrive on PC, the sort of thing that once would have stayed on PlayStation, while the unstoppable march of Warhammer 40K continues, and Tom Clancy is still putting his name on games despite being dead for five years.

The PC is in a strong place as a games machine—the consoles look exhausted as they gear up for another generational leap—and it's the place to come to find the most spectacular graphics and the cleverest use of AI, as this brief rundown of games to look out for in 2019 shows. There are a few sequels and remakes, too, though.

> "The consoles look exhausted as they gear up for another generational leap."

DEVELOPER AVALANCHE STUDIOS • **PUBLISHER** BETHESDA
DUE TBC 2019

RAGE 2

The sequel to id Software's post-apocalyptic FPS moves to Avalanche, home of Just Cause, where it picks up an open-world environment and a heavy nod to Fury Road. Once again, you're shooting mutants and driving messed-up vehicles, as well as lopping off heads with a razor-sharp boomerang, but this time it's using actual colors, rather than gray and brown.

DEVELOPER CODEMASTERS • **PUBLISHER** CODEMASTERS
DUE 02/26/19

DIRT RALLY 2

The official game of the FIA World Rallycross Championship, Dirt Rally 2 will take you to six rally locations around the world. The Dirt games have always been fun—there's a primal thrill in hurling a howling machine down muddy tracks and up gravelly mountains—and there's no reason to think this will be any different.

DEVELOPER REDLYNX/UBISOFT KIEV • PUBLISHER UBISOFT
DUE 02/12/19

TRIALS RISING

This ragdoll physics bike racer is poised to smash its way through unconvincing scenery following its beta at the end of 2018, bringing a new world-tour backdrop that plots courses around landmarks such as the Eiffel Tower. A new co-op mode will see two players control a single bike—a recipe for disaster if we ever heard one.

DEVELOPER SUMO DIGITAL • PUBLISHER MICROSOFT
DUE 02/15/19

CRACKDOWN 3

The Agency, a group of superpowered madmen, who've been known to drive jeeps straight up vertical buildings and blow the heads off hundreds of goons, is called into action after a terror attack takes out the power all around the world. We reckon we know what happens next, and it's not going to involve wiring puzzles.

DEVELOPER DECK 13
PUBLISHER FOCUS HOME INTERACTIVE
DUE TBC 2019

THE SURGE 2

A sci-fi take on the Souls games was the USP of the original release, and while The Surge didn't quite get the acclaim that FromSoftware's series has, it was definitely worth picking up for a sequel. An open-world action RPG in which you fight robots—you can expect oil to be splattered everywhere.

DEVELOPER BLIZZARD ENTERTAINMENT • PUBLISHER BLIZZARD ENTERTAINMENT DUE TBC 2019

WARCRAFT III: REFORGED

A remake of the 2002 RTS original made with the events of WOW in mind, it looks stunning. Hopefully, the retconned events and rebalanced gameplay will be as much of a time sink as first time. The original will get a patch, too, and owners will be able to play against Reforged players.

DEVELOPER BLUE BYTE • PUBLISHER UBISOFT
DUE FALL 2019

THE SETTLERS

German dev Blue Byte has picked up the reins of its venerable RTS series and completely updated it for modern PCs and Ubisoft's Snowdrop engine, so it's looking quite splendid. And if you're hot for some medieval town-building, there's an updated version of the original game on uPlay, too.

DEVELOPER REMEDY ENTERTAINMENT • PUBLISHER 505 GAMES DUE TBC 2019

CONTROL

Alan Wake dev Remedy is behind this third-person adventure in which a psychic, perhaps supernatural, woman fights her way through a brutalist skyscraper with a shape-changing pistol. After Alan Wake's American Nightmare, we suppose this was inevitable.

DEVELOPER FROMSOFTWARE
PUBLISHER PUB ACTIVISION
DUE 03/22/19

SEKIRO: SHADOWS DIE TWICE

Coming from FromSoftware, the studio behind Dark Souls, Armored Core, and Bloodborne, we're not expecting this to be an easy game. Set in Sengoku Japan, and following a mysterious one-armed warrior, Sekiro eschews the usual health bars in favor of one-hit kills, but you must knock your opponent off balance first in a graceful duel.

DEVELOPER CAPCOM • PUBLISHER CAPCOM
DUE 03/08/19

DEVIL MAY CRY 5

Not a traditional PC franchise, but the boundaries are dissolving now there's X86 at the heart of consoles, too. This one's about demon hunters, one of whom uses his motorbike and hat as weapons. There are also a lot of guns and swords, occasionally a massive fleshy scythe, and their arms come off. Very confusing, but a lot of fun, and spectacular in motion.

DEVELOPER BLUE BYTE • PUBLISHER UBISOFT
DUE FEBRUARY 2019

ANNO 1800

The Anno universe hits the industrial revolution, and sees you use the power of metal and steam engines to build a rural community into an industrialised city. The series has melded elements of grand strategy, such as diplomacy and warfare, on to its city-building core, so seeing what it can do with this tumultuous time in history will be extremely interesting.

DEVELOPER SNAPSHOT GAMES • PUBLISHER TBC
DUE JUNE 2019

PHOENIX POINT

From one of the men behind the original X-COM (that's 1994, not 2012) this is a spiritual successor to the series—so we know how it's going to play out. Turn- based combat, an alien invasion, and a resistance cell bravely battling both monsters and resource management trying to take the bad guys down. Frankly, we can't wait.

DEVELOPER TRIUMPH STUDIOS
PUBLISHER PARADOX INTERACTIVE
DUE TBC 2019

AGE OF WONDERS: PLANETFALL

Turn-based empire building in a sci-fi setting with multiple paths to victory sounds great, and when it comes from the dev behind Age of Wonders dating back to 1999, we like it even more. Bought by Paradox last year, the Dutch studio should now have the backing and resources it needs to knock this into orbit.

DEVELOPER CAPCOM • PUBLISHER CAPCOM
DUE NOW

RESIDENT EVIL 2

A remake of the 1998 PlayStation classic, this has learned from 20 years of game releases, and implemented things such as a checkpoint save system, controls that don't make you want to scream, and a proper PC release. Otherwise, it's exactly what you'd expect, as an army of the undead is fought off by two characters using guns, grenade launchers, and lockpicks.

DEVELOPER SQUARE ENIX • PUBLISHER SQUARE ENIX
DUE 03/05/19

LEFT ALIVE

A shooter set in the Front Mission universe—that means enormous stompy robots—Left Alive spins a tale of honor, revenge, and despair. And huge metal men. We'd be disappointed if you didn't get to blow at least one up, but the trailers so far have been heavy on characterisation and Metal Gear-like tactical shooting.

DEVELOPER UBISOFT SINGAPORE
PUBLISHER UBISOFT
DUE TBC 2019

SKULL & BONES

Open-world tactical action tends to bring up images of gruff men in black with guns—but this one is about pirates. The characters may still be gruff, but there's a chance of a shanty as you either pursue the single-player campaign or team up with five others to battle against other ships.

DEVELOPER MASSIVE ENTERTAINMENT • PUBLISHER UBISOFT
DUE 03/15/19

TOM CLANCY'S THE DIVISION 2

Another persistent-world multiplayer from Ubisoft, this time in Washington DC in summer. The viral apocalypse still took place, but you have new weapons and skills to deal with the enemies it caused.

DEVELOPER MOON STUDIOS • PUBLISHER MICROSOFT
DUE TBC 2019

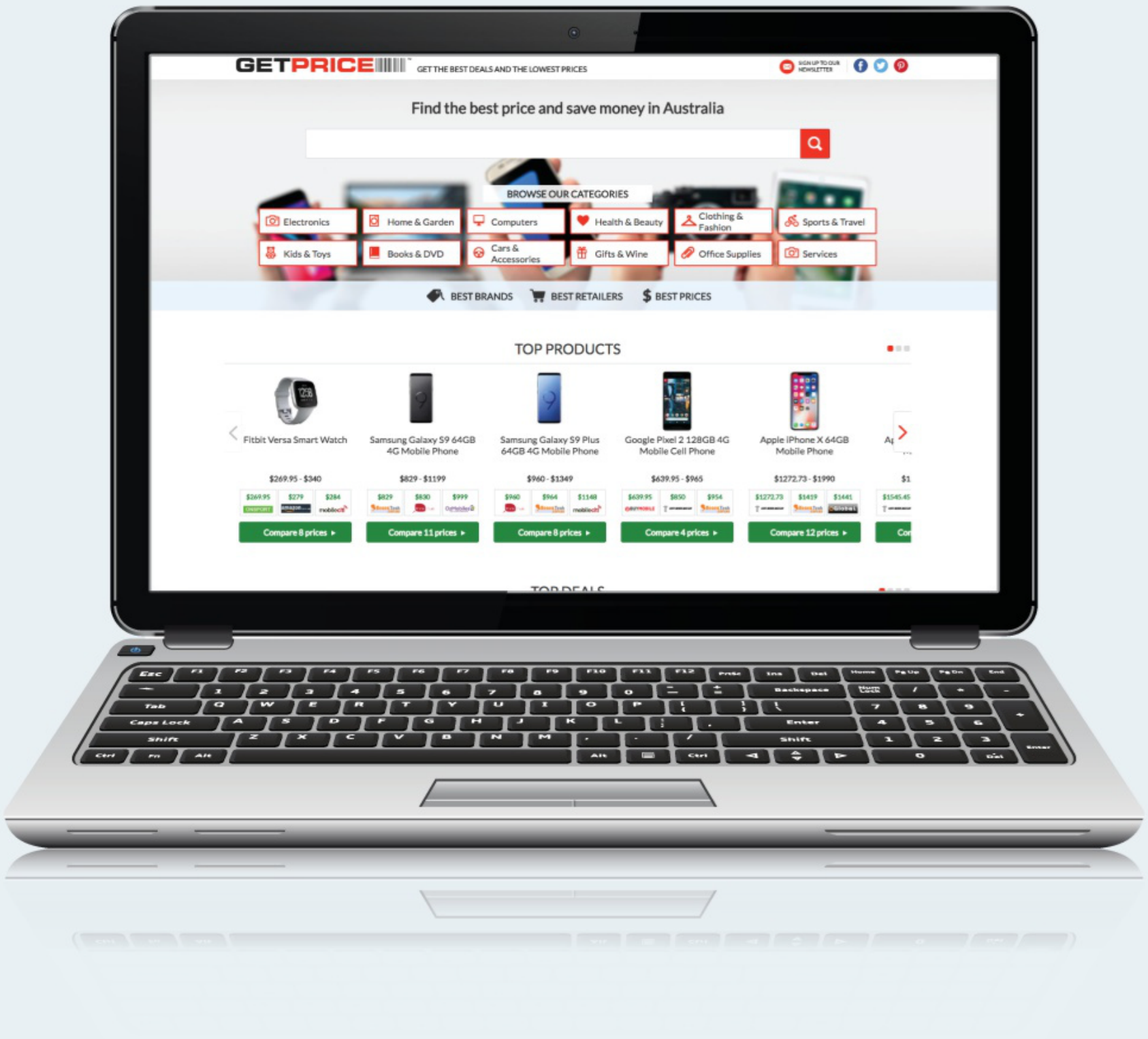
ORI AND THE WILL OF THE WISPS

Ori and the Blind Forest was a charming hit in 2015, and this promises more of the same. A guardian spirit moves between platforms and solves puzzles, while getting stronger and unlocking new areas.

DEVELOPER DONTNOD ENTERTAINMENT • PUBLISHER SQUARE ENIX DUE EPISODE 1 OUT NOW, OTHERS TBC

LIFE IS STRANGE II

Taking its structure from road movies, Sean is on the run from the police with his brother—who has mysterious powers— after their father was killed in what appears to be a supernatural incident.



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DEVELOPER YS NET/NEILO • PUBLISHER DEEP SILVER
DUE 08/27/19

SHENMUE III

Really? Yes, it seems it actually will come out. This "for the fans, by the fans" is actually by series creator Yu Suzuki, and sees martial artist Ryo journey into the Japanese mountains, where he meets a mysterious girl and a new enemy.

DEVELOPER FOCUS DOUBLE FINE • PUBLISHER MAJESCO ENTERTAINMENT DUE 04/19/19

PSYCHONAUTS 2

Here's something we don't see much of: a platform game. This crowdfunded sequel sees Raz and his psychic spies explore the mental landscapes of in-game characters, which become the game's levels, to be traversed using a range of powers.

DEVELOPER FOCUS POPTOP SOFTWARE • PUBLISHER GATHERING OF DEVELOPERS DUE NOW

TROPICO 6

The bonkers Caribbean dictator sim is back for another grasp at power, bringing large archipelagos to the series. You also send agents to other countries to steal monuments, make promises you can't keep, and gold-plate your palace.

DEVELOPER THE COALITION
PUBLISHER MICROSOFT
DUE TBC 2019

GEARS 5

Though no longer officially "Of War," the Gears are still fighting, now in a quest to discover the origin of the Locust Horde and, presumably, carve it in half with a chainsaw. JD Fenix, the protagonist of gaming's least subtle third-person blaster, returns, as does his dad Marcus, who's still voiced by Bender.

DEVELOPER MACHINEGAMES • PUBLISHER BETHESDA
DUE TBC 2019

WOLFENSTEIN: YOUNGBLOOD

MachineGames clearly wanted a change; this co-op game is set in the 1980s, and stars BJ's twin girls. The Nazis are still in power in some places, and need to be taken out with extreme prejudice. Goody!

DEVELOPER FOCUS HOME INTERACTIVE • PUBLISHER ASOBO STUDIO DUE TBC 2019

A PLAGUE TALE: INNOCENCE

Children struggling to survive the Hundred Years War is a jolly premise. Plus, they're stalked by hungry rats, which they must drive off with fire or lure into the path of knights. One to watch. From a distance.

DEVELOPER FOCUS HOME INTERACTIVE • PUBLISHER TINDALOS INTERACTIVE DUE NOW

BATTLEFLEET GOTHIC: ARMADA 2

Smash huge spaceships into even bigger biological terrors in this Warhammer 40,000 strategy. Twelve factions will be playable at launch, and ships eating other ships aren't out of the question.

DEVELOPER BANDAI NAMCO
PUBLISHER BANDAI NAMCO
DUE 02/01/19

ACE COMBAT 7: SKIES UNKNOWN

In the absence of Top Gun 2, this will have to do. Ace Combat is a series about hurling millions of dollars of jet around the skies and not caring too much. It's definitely not a simulation, because we're fairly sure the USAF doesn't do this many loops in normal operations, but it is fast and spectacular, with lots of gratifying explosions.

DEVELOPER 4A GAMES • **PUBLISHER** DEEP SILVER
DUE 02/22/19

METRO EXODUS

You know, like when everyone tries to get off the subway at once, only with even more guns. The third Metro game starts off in a harsh, post-apocalyptic winter, before sending protagonist Artyom out of the city and across an entire continent. No doubt this break from the claustrophobic norm will be interrupted by bitter fighting and mutated creatures, as usual.

DEVELOPER CREATIVE ASSEMBLY • **PUBLISHER** SEGA
DUE 02/22/19

TOTAL WAR: THREE KINGDOMS

Creative Assembly takes its historical battle series to China, where 11 factions are fighting it out to unify the country into the behemoth we know today. Romance mode, based on the classic novel Romance of the Three Kingdoms, will gift generals with superhuman powers, while in other modes those generals will form social connections and relationships. Before spilling lots of blood, of course.

DEVELOPER PARADOX DEVELOPMENT STUDIO • **PUBLISHER** PARADOX INTERACTIVE
DUE TBC 2019

IMPERATOR: ROME

More strategy from Paradox, this time with a sequel to 2008's Europa Universalis: Rome, and covering the establishment of the Roman Empire 2,500 years ago. While most of the game will see you battling on a grand scale, there will also be character management, in the style of Crusader Kings II.

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